Teachers' knowledge and practice: The role of secondary school students in technology integration

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Abstract

This research sought to understand how teachers' knowledge and practice with digital technology may be influenced through the active involvement of student digital leaders (SDLs) in the technology integration process in a secondary school setting. The literature review indicated that while there has been substantial research around approaches to technology integration in education and changes to teachers' knowledge and practice during attempts at integration, there have been few studies that actively involve students in the process.

The technological, pedagogical and content knowledge framework (Mishra & Koehler, 2006) is a popular way of exploring teachers' use of technology. However, this framework merely provided a lens which can be used to recognise and understand changes to the knowledge of teachers when using technology. As the focus of this research was on looking at how the knowledge and practice of teachers may be influenced by SDLs rather than looking at what happens and when it happens, a second lens, communities of practice as described by Wenger (1998) with roots in the theory of situated learning (Lave & Wenger, 1991), was used to analyse the sociocultural factors involved. Consequently, this research was a study of teachers working with SDLs, attempting to integrate technology in their practice. The focus was if these teachers are influenced by SDLs, how that happens. This was encapsulated in one research question: *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?*

To address this research question, a case study methodology was applied. Qualitative research methods were used to produce case studies presenting findings from professional learning sessions involving SDLs and seven teachers in one Australian secondary school. The research also drew on data from the school's principal, deputy principal and the SDLs. As this study featured SDLs working with teachers and in positions to potentially influence their knowledge and practice, careful analysis of the relationships between those involved was

necessary. It is also important to recognise that this was a small-scale study set in a particular context. There were specific structures in which the SDL program was implemented that involved team teaching and teachers learning how to teach project-based learning, often with little or no experience of such an approach. These contextual factors were considered in the analysis of data, subsequent discussions and propositions made.

The findings from this thesis support five propositions: (1) SDLs in peripheral and more liminal positions can influence teachers' knowledge and practice; (2) SDLs can influence teachers' technological pedagogical knowledge, not just their technological knowledge; (3) Both teachers' trajectories and their alignments can be key factors in the degree to which SDLs influence their knowledge and practice; (4) Team teaching structures provide opportunities for teachers to act on particular aspects of their identities. This affects how they develop joint enterprise with SDLs around technology integration; (5) The influence of SDLs on teachers' practice is closely linked to the amount of time teachers have to develop levels of mutual engagement and joint enterprise between themselves and SDLs.

This thesis addresses gaps in research on understanding how teachers' knowledge and practice when trying to integrate technology can be influenced by school students. It provides insight on issues such as teachers' identities, time factors and control related to teachers' professional responsibilities when teachers work with SDLs. Furthermore, the study also reveals that the use of a SDL strategy could be a useful approach to teachers' professional learning in the use of digital technologies in classrooms.

Declaration

This thesis is an original work of my research and contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

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Acknowledgements

In completing this thesis, I engaged the services of a professional editor, Antonina Petrolito, who provided copyediting of the thesis. She checked for adherence to submission guidelines; text flow and cross-chapter or cross-section mentions; cross-reference mentions of tables and figures; captions for figures and tables; grammar, typos, inconsistencies in punctuation, abbreviations and use of lower and upper case; correlation between in-text citations and references; and adherence to the preferred citation style.

This work has been a component of my life and my family's life for the last 7 to 8 years. While it has involved significant periods of isolated work and personal development, the involvement of others including my family, friends, colleagues and my supervisors, cannot be measured. To try to write accurate and full statements of gratitude and appreciation of the support I have received is virtually impossible and risks that moment of, 'I wished I had mentioned that' at a later date. Therefore, I will try to keep this brief and limit it to mentioning those people who stand head and shoulders above everyone else in this process. The order in which they are mentioned should in no way reflect their importance.

Through my doing the bare minimum in school, which enabled me to pass, and prolonged procrastination, which facilitated one hell of a good time, my Dad still supported me to succeed academically. The role model of hard work and Yorkshire grit he provided rubbed off in the end. However, I cannot talk about the role my Dad has played in this process without acknowledging my Mother. Her selfless dedication to her sons gave me the freedom to know no bounds to the possibilities that life offers. Without her, I know I would never have been in the position I am. Rest in peace, Mum. I am sorry you never got to see me graduate from this PhD.

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List of abbreviations

AITSL	Australian Institute for Teaching and School Leadership
CK	Content Knowledge
CoP	Communities of Practice
ICT	Information Communication Technology
IT	Information Technology
PBL	Project Based Learning
PCK	Pedagogical Content Knowledge
PK	Pedagogical Knowledge
SDL	Student Digital Leaders
TCK	Technological Content Knowledge
TPK	Technological Pedagogical Knowledge
TPACK	Technological, Pedagogical, and Content Knowledge
XK	Contextual Knowledge in TPACK
3D	Three Dimensional

Chapter 1: Introduction

During 2009, I became aware of the concept of student digital leaders (SDLs) through colleagues in other secondary schools in the United Kingdom. This concept recruited students in various roles in schools to assist teachers in their use of hardware and software. As a teacher and secondary school faculty leader in information technology, I have always been interested in the application of digital technologies and given that, at the time, I was also completing a Master in Multimedia and eLearning, I introduced SDLs at my school to try to improve the use of computers in teaching and learning. Teachers, school leaders, parents and students involved at the time saw that the work of these SDLs had an enormous effect on the development and use of digital technology in their school (Jackson, 2012). Similar positive experiences have been witnessed by those involved in other schools that have set up SDL schemes in the United Kingdom (Digital Leader Network, 2012). In other countries, there are similar schemes and related programs (e.g., see http://www.genyes.org; http://www.ozdls.com.au) or the Genius Bar concept (Wong et al., 2015), which have espoused the benefits of involving students in the integration of technology in various forms.

Having spent the last 8 years in senior leadership positions in schools in Australia, I have been able to further experiment with the student SDL initiative, including variations in student role, teacher preparation, administrative support and wider involvement in professional learning. Labelling the SDLs as students in active roles in technology integration indicates to me that SDLs can have a wide-ranging impact and sustainable positive influence on teaching and learning. However, it is still unclear how this change occurs; what the effects are on teachers' knowledge and practice. Consequently, this research investigated how teachers, students and the senior leaders engage with each other to shape pedagogical technology integration when SDLs are introduced to work with teachers trying to influence their knowledge and practice.

1.1. Student SDLs and technology integration

For some time, views on the underlying reasons behind the integration of digital technologies into education, the way to integrate technology and the degree of integration that has been achieved differ. This section considers those views and outlines the position of this research in respect of these.

Views have been expressed over the potential benefits for teachers who adopt digital tools as part of their practice. Teachers in countries that are part of the Organisation for Economic Co-operation and Development have been seduced to develop their skills in education technology by the advertisements of hardware and software companies and aspirational statements made by governments (M. Phillips, 2016). In addition, there have been requirements for achieving standards set by teacher registration bodies as well as investment in both digital infrastructure and professional learning opportunities in education. These pressures have reinforced the assumption that digital technologies enhance teaching and learning. In Australia, a report commissioned by the Federal Government claimed, "achieving enhanced education outcomes in Australian schools is increasingly linked to the pace of digital education uptake" (Alexander, 2013, p. 5). This clearly demonstrates a perceived connection between the use of digital technologies and the resultant improvement in the current educational landscape.

Research also points to the potential benefits associated with teachers' adoption of digital technologies. Investigations into areas such as technology enhanced learning (e.g., see Carneiro et al., 2012; Cerratto-Pargman et al., 2012; Dror et al., 2011; Kim & Hannafin, 2011; Manouselis et al., 2011; Vittorini et al., 2012) and computer-assisted learning (e.g., see Chambers et al., 2011; Karaksha et al., 2011; McDowall & Jackling, 2006; Ross et al., 2011; Sosa et al., 2011) reinforce the connection between technology and the improvement of learning and teaching.

In contrast, comments about research being "driven by an underlying belief that digital technologies are – in some way – capable of improving education" (Selwyn, 2011, p. 713) highlight scepticism of this view. Government-funded research in other countries in the Organisation for Economic Co-operation and Development reveal similar cautious observations, "while there has been an impact on learning and teaching … it has not yet reached the point where it can be said to have transformed the educational process." (Condie & Munro, 2007, p. 76). Thus, it could be argued that considerable effort has been invested in researching the learning potential of new or emerging technologies rather than the reality.

The idea that there is a disjuncture between the rhetoric and the reality or a division between the potential and the practice, when it comes to the educational uses of digital technologies in teaching and learning, can be seen in academic literature. Comments such as "hype about how it would transform education" (Warr et al., 2019, p. 2558), "education is on the brink of being transformed through learning technologies; however, it has been on that brink for some decades now" (Laurillard, 2008, p. 1) or "excitement above evidence" (Luckin et al., 2012, p. 63) highlight that case studies, the basis of many investigations, remain somewhat distinct from the "state of the actual" (Selwyn, 2008, p. 84). A number of researchers examining teachers' pedagogical adoption of information and communication technologies (ICT) in schools claim that technology integration is not happening, happening too slowly or happening with little or no effect on student learning (Cheung & Slavin, 2013; Cuban et al., 2001; Delgado et al., 2015; Ertmer, 1999; Hattie, 2008; Makki et al., 2018; Mumtaz, 2000; Parisot, 1995; Somekh, 2008; Straub, 2009; Tondeur et al., 2017).

Negative views on the realities of technology integration in schools are evident in criticisms of the Australian Government's strategy, suggesting that little may have changed (Facchinetti, 2010). Findings such as these are not isolated to Australia, however. The Innovative Teaching and Learning research project examined teachers' integration of digital technologies as part of their classroom practice in nine countries concluding:

> While researchers saw many examples of specific practices that were innovative within a given national context (such as students working in teams or developing presentations based on current social issues they had researched on the Internet), descriptions of learning activities that incorporated a coherent set of innovative practices were quite rare, and the 21st century skill-building opportunities offered by the typical learning activity remains low. (Shear et al., 2011, p. 26)

Shear et al.'s (2011) findings in the Innovative Teaching and Learning research project echo those of M. Cox et al. (2003) and Cuban et al. (2001), suggesting that there has been little meaningful change in teachers' "state of the actual" uses of technology (Selwyn, 2008, p. 84), despite the technological advances witnessed in contemporary society. Despite this body of research questioning the realities and effects of technology integration in education, pressure to increasingly use digital technology in teaching continues for teachers and schools.

The National Education Technology Plan in the United States of America (U.S. Department of Education, 2017) and Singapore's Education Technology Plan (Singapore Ministry of Education, 2021) are two of many examples of governments mandating the use of technology in schools. This is reflected in Australia in the General Capabilities elements of the Australian Curriculum, where teachers are expected to incorporate information and communication technology (ICT) within their learning area content (Australian Curriculum, Assessment and Reporting Authority, n.d.). The Australian Institute for Teaching and School Leadership (AITSL, 2011, p. 11) expects graduate teachers to develop "teaching strategies for using ICT to expand curriculum learning opportunities for students". It outlines further developments expected of practising teachers, where leading teachers should "support colleagues ... to select and use ICT with effective teaching strategies to expand learning opportunities and content knowledge for all students" (p. 11). This suggests not only use of technology in teaching practice but an increase in related professional knowledge and skills. In addition to the AITSL recommendations for teachers, the Australian Curriculum focuses on students, stating that in the General Capabilities in ICT "students develop knowledge, skills and dispositions around ICT and its use" (Australian Curriculum, Assessment and Reporting Authority, 2014).

Despite the expectation of students and teachers to use technology across the curriculum and calls for reform of teaching and learning in schools, the disconnect between policy and practice seems to continue (Luckin et al., 2012, Warr et al., 2019). As to whether those desired changes have occurred thus far seems to be down to a focus on the technology and not the teaching (Brady et al., 2012; Luckin et al., 2012). If the views of Selwyn (2008) that the real demands are for changes in pedagogical approaches in schools are to be supported, using technology to improve teaching practice (Ertmer, 1999), providing an "opportunity to reconceptualise teaching and learning in the 21st century" (Moyle, 2010, p. 1) and bring about qualitative changes in education (Su, 2009), it could be argued that integrating technology facilitates those changes. However, research to date suggests that technology integration in isolation is not capable of supporting these changes. Hence, for this research, it is that combined effect of technology integration and changes in teachers' knowledge and practice that is being considered not through an examination of teachers or students in isolation as is evident in previous bodies of literature but by attempting to develop a framework through which teachers' knowledge and practice may be influenced by students in active roles.

1.2. The scope of this research

This research study had students actively involved in technology integration. It considers where student SDLs are given active involvement in the processes of assisting teachers in using digital technologies and any influence they have on the teachers. Use of the terms: technology, technology integration and education technology appear throughout the study. It is appreciated that technology can be defined in a broader sense to include all manner of equipment, some of which is non-digital. Similarly, the term educational technology may apply to the use of tools, to theory and practice in education, some of which applies to areas beyond use of computers. However, this study examines teachers attempting to learn and then use specific digital technology software in their teaching practice. Hence, all terminology related to technology and its integration refer to digital technologies. The findings will focus

on how the teachers' knowledge and practice were influenced by the SDLs.

The scope of this research is limited, however, as it was conducted in one secondary school involving, at the outset, 16 teachers. It is also restricted to analysis of the teachers and their practice. It does not examine any effects on the SDLs or the learning of the students taught by the teachers involved.

1.3. Research aims and questions

The aim of this research was to understand if teachers' knowledge and practice with digital technology can be influenced through increasing the active involvement of students in the technology integration process. Consequently, this research was driven by one main research question*: How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?*

1.4. Overview of the chapters

The thesis is organised according to the following structure:

- *Chapter 2: Literature review*

The second chapter provides a comprehensive literature review of the two lenses used in this study – the technological pedagogical content knowledge (TPACK) (Mishra & Koehler, 2006) and the community of practice (CoP) (Wenger, 1998) frameworks – as well as literature on the active involvement of students in technology integration. It opens with a look at the main issues around technology integration into education and then reviews literature that shows how the TPACK framework has been developed and used to look at changes in teachers' knowledge when trying to integrate technology. The chapter then looks at research papers where students have been actively involved in trying to influence knowledge and practice where the focus is on technology integration and other elements of a teacher's practice. Literature around the second of the lenses, CoP, is then reviewed with a detailed

look at identity and practice to establish an understanding of how the social relationships work between SDLs and teachers during the study. The chapter concludes that there are gaps in research on students in active roles trying to influence teachers' knowledge and practice when attempting to integrate technology but, more importantly, on understanding how that happens.

- *Chapter 3: Methodology*

This chapter argues that a qualitative multiple-case study approach is the most appropriate design for this research study. The chapter provides an insight into how data is generated. It justifies the selection of data collection and analysis methods by examining the challenges in case study research, specifically looking at positionality in participant observation and methods used to address issues of bias. The coding process used and how and why it was developed are described to provide an understanding of the data analysis in this study.

- *Chapter 4: Case studies*

This is a relatively short chapter that provides foundational data that the case studies rely on. It presents an overview of the teachers and their views at the outset of this research study in relation to technology and in relation to working with SDLs. This is critical in understanding how the teachers saw their skills, experience and confidence at the outset of this research as well as their views on using technology in their practice.

- *Chapter 5: Case study 1 – Paul & Roger*

This chapter presents the first case studies and focuses on two teachers who seem to fit the descriptions of old-timer and newcomer provided in CoP research. It looks at how they operate as a teaching team and their involvement in the three stages of professional development organised for this study. Their relationship with each other as well as with the SDLs are discussed, with the focus on understanding how their knowledge and practice was influenced by working with the SDLs. The case study provides three major insights: Firstly, the roles that the teachers take in a teaching team and their positions in CoPs can determine

the degree of influence that SDLs have on their knowledge and practice. Secondly, the relationships teachers develop with SDLs are significant in determining the degree to which SDLs can influence, and time is critical factor in this. Thirdly, there are limitations to the influence SDLs can have on teachers who consider themselves relatively high in confidence and skills in using technology, and SDLs' effectiveness is linked to teachers developing a learner mindset.

- *Chapter 6: Case study 2 – Marg & Faith*

This chapter features two teachers who can be seen as CoP newcomers, how they work together in a teaching team and how they rely on the assistance of more experienced teachers. This case study challenges the traditional newcomer/old-timer relationship described by Wenger (1998) and provides a different perspective on the idea of distributed TPACK. There is a focus on particular aspects of identity, specifically trajectories and how they play a role in the ability of teachers to be influenced by SDLs when trying to integrate technology into their practice. This case study also shows that contextual factors such as the teaching space can be significant, particularly when SDLs provide in-class assistance to teachers.

- *Chapter 7: Case study 3 – Tom & Emma*

This chapter shows how both teachers seem to develop elements of their TPACK and practice through working with the SDLs, despite significant contrasts in their identities and their approaches to working with the SDLs. The role that alignment plays for both teachers and how it contributes to the formation of their identity and learning from the SDLs is revealed. Despite the way that both teachers develop working relationships with SDLs around technology integration, there are issues in respect of professional boundaries between themselves and the SDLs that seemingly cannot be overcome. There is also a discussion on SDLs in brokering roles.

- *Chapter 8: Case study 4 – Finn*

This chapter features one teacher whose involvement with the SDLs during software

training and pedagogical discussion sessions highlights how distributed knowledge can be shared with SDLs. It shows that working with SDLs can enable teachers to improve their technological pedagogical knowledge (TPK) as well as their technological knowledge (TK) in the TPACK framework. However, the influence of SDLs is dependent on the existence of a joint enterprise where the teachers' understandings and interpretations of school culture determine how they participate in professional development sessions with the SDLs.

- *Chapter 9: Discussion*

This chapter discusses the findings from all the case studies in this research. There is analysis of the barriers that SDLs face due to the teachers' professional responsibilities. This positions the SDLs on the periphery of teacher CoPs. However, they are able to influence teachers and practice from these positions, brokering ideas and practice as they work with different teachers. There is a discussion on distributed knowledge and how SDLs are able to influence teachers' pedagogy when planning to teach and during in-class activities. The role of specific aspects of teachers' identities are discussed, namely alignment and trajectories. These determine how teachers react to the SDLs and to the integration of technology that the SDLs are attempting to influence. Discussions are also provided on how team-teaching structures play a role in teachers being influenced by SDLs, the issue of time spent with SDLs to develop mutual engagement and joint enterprise and the significance of contextual and organisational aspects,

- *Chapter 10: Conclusion*

The final chapter presents five propositions that are distilled from the discussion points and their implications and recommendations for future research while also recognising the limitations of a study of this scale. The propositions highlight how SDLs can influence teachers' knowledge and practice, the types of knowledge they can influence and what factors play a significant part in affecting the degree of that influence. These propositions offer extensions to research with both the TPACK framework and in CoP as well as answering the

research question. The conclusion provides a summary of the thesis along with theoretical and practical implications for in-service teachers' TPACK enactment as well as suggestions for the critical use of both CoP and TPACK theories Although the TPACK framework was developed to understand what teachers need to know about technology to teach effectively and how can teachers acquire this knowledge (Mishra & Koehler, 2006), there has been little investigation on teachers' knowledge acquisition. The current research addresses this gap in the literature; it indicates not only the appropriateness of a CoP as a theoretical lens through which teachers' TPACK development can be understood but also how context as identity and practice can help explain teachers' TPACK development and enactment. While not forgetting the context of this research and the limitations on generalisability, the findings support five theoretical propositions regarding the role of CoPs in shaping teachers' TPACK enactment. The thesis concludes with an outline of suggested future research avenues drawn from each of the cases as well as potentially significant issues which emerged in the data but which were not further investigated due to the scope and limitations of this research.

Chapter 2: Literature review

Careful study of the research question reveals that the main aim in this study was to investigate what happens to teachers' knowledge and practice using digital technologies when students have various active roles in the school's technology integration processes. It is therefore vital to commence this literature review by establishing clarity in respect of the term *technology integration* and having some way of unpacking the complexity of technology integration. During this distillation of technology integration, the issues of context and of distributed knowledge will be significant factors as this research study looks at teachers teaching in teams, in various contexts, assisted by SDLs.

After reviewing literature on technology integration, discussions focusing on literature that depict students in active roles, influencing teachers' knowledge and practice will be the focus. These will provide related experiences and practical considerations that need to be understood for this research. This will include some research papers where the focus is technology integration and others where it is not.

Lastly, literature on CoPs provides an insight into understanding the school as a site of learning with interactions between the teachers and students involved. Understanding these interactions will provide insight into how such issues as power and relationships develop within teachers' CoPs when the typical roles of students and teachers change. Exploring teacher knowledge and practice and the active role of students and understanding teachers as learners in a CoP will enable research to be designed to answer the driving question: *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?*

2.1. Technology integration

Papert's predictions in the early 1980s were that computers can play a major part in changing teaching and learning: "computer technology can change learning … by suggesting

new and different kinds of relationships to knowledge and to learning" (Papert, 1984, p. 4). Despite being at the very early stages of computer use for teaching and learning, Papert was already foreseeing situations where the way that traditional learning occurs may have to change. On closer scrutiny, Papert's views suggest the need to develop education systems, pedagogical approaches and the capacity of those in education to work within a radically different environment than what was typical of the time (Yelland, 2006), hence the need to concentrate on comprehensive, structured technology integration in education.

Achieving Papert's (1984) utopian views of computer-rich education seems far more complex in terms of implementation and teacher adoption (Bauer 2005; Handal, 2004; C. Kim et al., 2013; Kopcha, 2012) than perhaps Papert anticipated. In an opinion piece for the *New York Times*, Kirp (2014) claimed that the drive for teachers to use technology can overshadow the need to train, equip and improve. Similarly, there can be too much focus on the technology and not enough attention given to the need for high-quality teaching (Bharti, 2014).

According to Okojie (2006), integrating technology involves examining relationships with technology, studying the theories on its use as well as looking at strategies for implementation and measurement. The various levels of management and staff in an institution are often participants (Divaharan & Ping, 2010), with the emphasis on having teachers prepared in approaches to instruction (R. L. Bell et al., 2013). Technology integration in education should focus on teaching and learning (Cooke, 2012; Peeraer & Van Petegem, 2012).

The worldwide pandemic of the last few years has highlighted the significant roles that technology plays in education. However, issues remain in the technology integration process. There is still no consensus on strategies for achieving systematic educational technology integration in educational settings (Hart, 2007; J. Harris, 2005; Lindberg et al., 2017). Despite such issues, all of the aforementioned papers highlight the need to focus on teachers' understanding of educational technology and how this relates to their existing knowledge.

This has led to more research centred on "integrating pedagogy and content with technology" (Tee & Lee, 2011, p. 89), looking primarily at what teachers understand of the technology available in their practice and how to use it to achieve certain learning outcomes. The drive towards understanding educational technology and its connection with a teacher's existing knowledge can be seen in the abundance of studies based on the theory of TPACK, which built on the framework on pedagogical content knowledge (PCK) by Shulman (1986b).

TPACK provides a "framework that identifies the knowledge teachers need to teach effectively with technology" (Koehler, Mishra, Akcaoglu et al., 2013, p. 2); and according to Redmond and Lock (2019), it "has been embraced by teacher educators for research and teaching purposes" (p. 46). TPACK's popularity can be seen in that it "has been widely applied for the design and evaluation of teacher professional development courses" (Deng et al., 2017, p. 1). However, it has also become a popular framework for looking at the application of technology in teaching (e.g., see Buss et al., 2018).

In a review of TPACK, where they examined 54 journals, Chai et al. (2013) recognised the diversity of the framework in relation to education and technology, summarising it as "a powerful framework which has many potential generative uses" (p. 31). They highlighted its growing popularity for research in education technology and accentuated the scope for further developments using the framework in "many possible directions for future research" (p. 45). The reality of these "possible directions" has been reflected in the body of literature using the TPACK framework since the publication of Chai et al.'s work; for example, Koh and Chai (2014) examined lesson design by in-service and pre-service teachers in Singapore; Tømte et al. (2015) studied online teacher professional learning programs to see if they enhance innovation in technology-integrated teaching practice at two Scandinavian universities; Muir et al. (2016) showed a teacher using an interactive whiteboard to teach mathematics to primary-age students in Australia; Durdu and Dag (2017) analysed the development of pre-service teachers learning and teaching with technology in Turkey; and Redmond and Lock (2019) investigated the perceptions of pre-service secondary school teachers in Australia.

Greater scrutiny of the work of Chai et al. (2013) revealed that 51 of the 54 papers they studied support constructivist approaches to education. Constructivism and its relevance to my research will be discussed in greater detail in Section 2.2. It is also worth noting here that "project-based or inquiry-based learning were common among qualitative case studies" (p. 43) in the papers they reviewed. Project-based learning (PBL) will also be a feature of this research study and will be discussed in the Methodology section.

Chai et al.'s (2013) intention was not only to examine existing research papers to see what trends were, however. Their work was also aimed at identifying gaps in the development of the TPACK framework, indicating areas for further or deeper research. One of these was in respect of teacher beliefs: "more studies on how teachers' beliefs shape their TPACK and classroom practices are needed to clarify the relationships between beliefs, knowledge and skills" (p. 38). This issue of teacher beliefs and their perceptions at the outset of using technology in teaching will feature prominently in my research study.

Chai et al. (2013) highlighted further areas for development in TPACK research. They argued that issues of context and the types of technology integration practices used in classrooms need to be explored. There was a call for more research looking at "contextual affordances and constraints" (p. 38) and how these affect a teacher's TPACK, just as there had been a call for more research on teacher beliefs. Again, this will be a feature of my research, and further literature will be examined in this respect in Section 2.1. (Knowledge use and context in TPACK). As regards technology integration practices used in classrooms, there were several identified but none which look at the idea of students playing an active role in directly influencing the knowledge and practice of teachers as is intended with SDLs in my research.

Harris et al. (2017) demonstrated the dissemination and reach of TPACK research saying that it was used in approximately 1200 research publications. However, at the same time, they stressed how such a widespread application of the framework has opened up avenues for

further research, listing context and the issue of knowing and doing as two key areas. Both of these areas are pertinent to answering my research question but the "interpretations, and implementations of the construct; emerging and varied ways to measure TPACK" (Harris et al., 2017, p. 1) support the arguments presented in this section that technology integration is far from a simple concept. Allied to this are the complexities in applying TPACK effectively. According to Koehler and Mishra (2009), "the complexity inherent in each knowledge component or the complexities of the relationships among the components can lead to oversimplified solutions or failure" (p. 66). Such intricacies in TPACK remain in the views of Koehler and Mishra (2013), where they described the TPACK framework "as a complex interaction among three bodies of knowledge: content, pedagogy, and technology" (p. 13).

Describing all of these complexities serves to highlight the depth of the TPACK framework. However, it can also be seen in the comments above from Koehler and Mishra (2009) and from Koehler and Mishra (2013) that the focal point of TPACK is knowledge. These demonstrate their potential in providing a lens to answer the research question: *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?* It is from this basis that further literature on TPACK will be reviewed in the next section.

The TPACK framework

The TPACK framework was introduced by Mishra and Koehler (2006) as an extension to the work of Shulman (1986b) and the concept of focusing on the complexities of teaching that require consideration of pedagogy and content knowledge (PCK) together. The proliferation of technology in education and its significance in teaching practice was the basis for research that culminated in adding technological knowledge (TK) as a third element to Shulman's framework (Mishra & Koehler, 2006). The model was intended to add to research on teacher education and development (Koehler & Mishra, 2009) but continues to be widely used in training pre-service teachers (Durdu & Dag, 2017), in teacher professional learning programs

(Chai, 2019) and in analysis of teachers in classroom situations (Muir et al., 2016). In order to properly understand how the TPACK model, the elements of knowledge considered within it, namely TK, pedagogical knowledge (PK) and content knowledge (CK), need to be explained before the intersection of these elements is considered.

TK

TK, according to Mishra and Koehler (2006), is not just related to digital technologies. It is "about standard technologies, such as books, chalk and blackboard, and more advanced technologies, such as the Internet and digital video" (p. 1027). While providing the scope to apply TPACK to the trend for rapid development in the use of technology, relying on such a broad definition that encompasses so many teaching tools has been criticised as "an example of the current lack of clarity in the TPACK framework" (Graham, 2011, p. 1963). By including both digital and non-digital technologies in the definition of TK, Graham argued that such a definition fails "to clearly delineate the scope of TPACK" (p. 1963), meaning that "every teaching situation would require TPACK because one doesn't typically teach without using some kind of tool" (p. 1963). Hence, there is a lack of clarity in application and understanding of how TPACK can be used to better understand digital technology integration in education.

Graham (2011) suggested that S. Cox (2008) provided some clarity in her interpretation of TK. She categorised technologies into *transparent* and *emerging*, where the transparent are in use universally and the emerging technologies are either "being investigated or introduced into a learning environment" (Graham, 2011, p. 1965). Graham advocated for this approach as "it allows transparent technologies that are not the focus of a particular analysis to be encompassed within PCK" (p. 1965) which, in turn, allows for specific technologies to be put under the spotlight for analysis via the TPACK framework.

It is important to note that the notion of having technology, the knowledge around a piece of technology and its uses for teaching and learning as transparent or emerging is not an

either/or situation, according to S. Cox (2008). Instead, the key is to recognise the "'sliding' nature of TCK, TPK, and TPACK" (p. 65). S. Cox described an example of a book with reference to the use of technology. This supports Mishra and Koehler (2006) in seeing technology as far more than digital. Books are significant, according to S. Cox, in that they represent technology that teachers have used for a significant period of time and, as such, they have "become transparent or ubiquitous" (p. 65) as opposed to examples of technology where teachers are not so knowledgeable or have been exposed to the same extent.

M. Phillips and Harris (2018) based their paper on S. Cox's (2008, p. 65) depiction of a sliding scale of technology, where "TPK transforms into pedagogical knowledge as the emphasis on the technology is no longer needed". They saw that the familiarity with some technologies means "teachers did not have to think much about how to use these technologies in pedagogical ways" (p. 2110); therefore, the teachers in these situations "would be using their PCK, rather than their TPACK" (p. 2114). M. Phillips and Harris went on to argue that such views on technology and associated teachers' knowledge follow what Shulman (1986a) originally "envisioned when he proposed a seven-part knowledge base for teaching, of which PCK was only one component" (p. 2113). Thus, they should provide clarification and precision in TPACK research.

Recommendations from M. Phillips and Harris (2018) that TPACK research should set out to establish whether technology is transparent or emerging in the teachers they are analysing has, at the time of writing, been applied only by Niess et al. (2019), but it is a factor that needs to be considered in my research study. Understanding the prior knowledge and how established the technology in question is to the teachers will enable the appropriate aspect of the TPACK framework to be used.

Applying the interpretation of TK by S. Cox (2008) also provides support for the argument that "technology knowledge (TK) is always in a state of flux" (Koehler & Mishra, 2009, p. 64). According to M. D. Phillips (2014, p. 50), the explanations of Mishra and Koehler (2006)

and Koehler and Mishra (2009) "promote the idea of technology knowledge as less of a static, compartmentalised notion but one that evolves as an individual's open-ended interaction with technology changes over time". Hence, TK is more than just knowing how to use a tool superficially. What is required is "deeper, more essential understanding and mastery" (Mishra & Koehler, 2006, p. 1027) "to recognize when information technology can assist or impede the achievement of a goal" (Koehler & Mishra, 2009, p. 64).

PK

Shulman (1986b, p. 8) defined PK as "how teachers manage their classrooms, organize activities, allocate time and turns, structure assignments, ascribe praise and blame, formulate the levels of their questions, plan lessons, and judge general student understanding". Referring to PK as "deep knowledge", Mishra and Koehler (2006, p. 1026) seemed to emphasise the extent of the knowledge a teacher is expected to develop. However, this could also be interpreted as the importance of such knowledge. Mishra and Koehler (2006) offered nothing more to provide clarity in this respect, and Koehler and Mishra (2009) offered the same definition.

Mishra and Koehler (2006) also said that PK is "a generic form of knowledge" (p. 1026), as it is intended to be a spread of knowledge that is independent of disciplines. They then went on to talk about what should be included in PK saying, "it includes knowledge about techniques or methods used in the classroom; the nature of the target audience; and strategies for evaluating student understanding" (p. 1026). In a study on pre-service teachers, Schmidt et al. (2009, p. 132) offered more specific examples: "classroom management, assessment, lesson plan development, and student learning" in applying TPACK. In that same paper, teachers judged themselves in terms of classroom management, assessing student performance in class, adapting teaching style based on learners, being able to assess students in different ways, being able to use a range of teaching approaches, knowing common pitfalls in understanding for students and adapting teaching based on student understanding. Schmidt et al. (2009) provided support for both the way that PK "transcends disciplines" (M. D.

Phillips, 2014, p. 51) and suggested that "deep knowledge" (Mishra & Koehler, 2006, p. 1026) should be interpreted as the extent of the knowledge teachers are expected to develop.

Another analysis of TPACK provided responses that have some parallels to Schmidt et al. (2009)'s findings in respect of PK, but there are differences. S. Cox (2009) described how PK "may include strategies for motivating students, communicating with students and parents, presenting information to students, and classroom management among many other things" (p. 62). Their descriptions were clearly more general than those of Schmidt et al. (2009), but their closing remark, "among many other things" (p. 62) provides the potential for a very open interpretation of PK. Such lack of specificity in respect of what PK includes could be argued to contribute to how some researchers misinterpret PK to be a part of TCK when it is clearly separate in the TPACK framework (Graham, 2011). Regardless of the specific elements identified and interpretations of exactly what PK breaks down into, understanding that PK is in-depth knowledge that can be applied generally in teaching practice is the key.

CK

According to Mishra and Koehler (2006), CK "is knowledge about the actual subject matter that is to be learned or taught" (p. 1026). According to S. Cox (2008), definitions of PK and TK by Mishra and Koehler referred to knowledge as, "deep". In those sections, types of technologies were described as: "standard", "advanced", "transparent" or "emerging" (Section 2.1. – TK; PK). Looking at CK comparatively, it could be argued that such a simple statement lacking in adjectives suggests that it is not as significant or is easier to obtain than PK or TK. However, CK is a core component of the TPACK framework. Its significance was highlighted, in that a lack of proper understanding of CK can lead teachers to "misrepresent" (Mishra & Koehler, 2006, p. 1026) subjects they teach.

There have been supporting views focusing on what may happen if teachers do not have adequate CK. Harris et al. (2009) stated that it "can be quite prohibitive; students can develop and retain epistemologically incorrect conceptions about and within the content area" (p.

397). Having strong CK has also been related to competence (Jita, 2016). CK goes "beyond knowledge of the facts or concepts of a domain. It requires understanding the structures of the subject matter" (Shulman, 1986b, p. 9). All of these views support the significance of CK in the TPACK framework.

Mishra and Koehler (2006) talked about how "teachers must know and understand the subjects that they teach" (p. 1206). This suggests that there are some complexities in teachers developing CK. However, interpretations of CK have shown some disparities in this regard. Schmidt et al. (2009) stated that, "content knowledge (CK), refers to the knowledge teachers must know about for the content they are going to teach and how the nature of that knowledge is different for various content areas" (p. 132). The latter part of this statement refers to the "nature" of knowledge, in other words, its essential characteristics and how these characteristics must be known in relation to different content areas. Harris et al. (2009) stated that, "knowledge and the nature of inquiry differ greatly among content areas, and it is critically important that teachers understand the disciplinary 'habits of mind' appropriate to the subject matter that they teach" (p. 397). This has correlations to understanding the "nature" of knowledge but seems to go further, suggesting CK involves knowing how students typically react to elements of a discipline. Knowing what to do in reaction to "habits of mind" and the "nature of knowledge" in CK falls into the circle of pedagogy. CK "is independent of pedagogical activities or how one might use those representations to teach" (S. Cox, 2009, p. 63), which is where the intersection of the core components are used in the TPACK framework.

TPACK intersections

TK, PK and CK are core components of knowledge with their own characteristics, expectations and issues. They were discussed independently of each other in Section 2.1 – TK; PK; CK). This was intended to highlight the significance of understanding these in isolation. However, these forms of knowledge are also interconnected. The relationships between domains of knowledge enables answers to "questions for disciplined inquiry into

teacher education" (Shulman, 1986b, p. 9). Such multifaceted views on teacher knowledge are driven by the belief that "teaching is a highly complex activity that draws on many kinds of knowledge" (Mishra & Koehler, 2006, p. 1020). According to Mishra and Koehler (2006), TK, PK and CK form the foundations of knowledge that a teacher needs to integrate technology in their practice.

With demands to embody elements of teacher knowledge both independent of each other and interconnected, TPACK is commonly represented by intersecting circles in a Venn diagram:

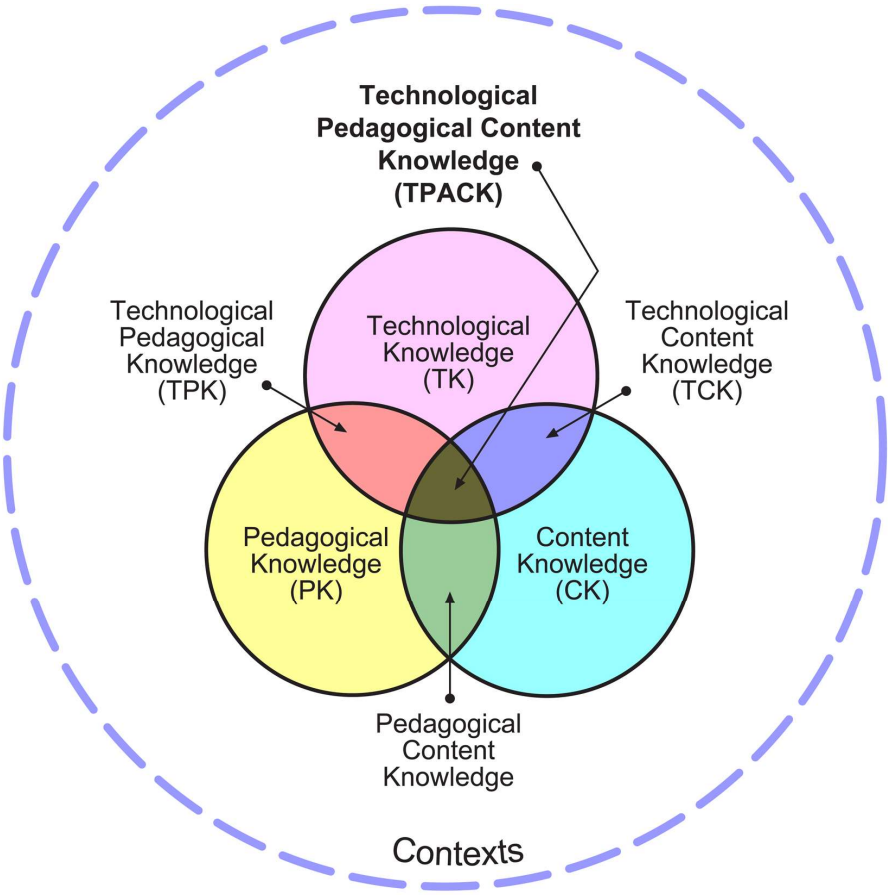

Figure 1: The TPACK model. (Mishra & Koehler, 2012). Reproduced by permission of the publisher, © 2012 by tpack.org

Graham (2011) described the TPACK framework as where "three core types of knowledge results in four additional types of knowledge: pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK), technological content knowledge (TCK), and

technological pedagogical content knowledge (TPACK)" (p. 5). The intersections symbolise connections between TK, PK and CK and are borne out of the views that teacher training could improve if the knowledge concepts were not treated in isolation (Hughes, 2005; Shulman, 1986b). The underlying premise of Mishra and Koehler's model in Figure 1 is that teachers struggle to integrate technology effectively due to their knowledge of technology being treated as unconnected to content and pedagogy. It is important to discuss the model's intersection of PCK first as this idea of the relationship between these knowledge forms and its significance was proposed in earlier research by Shulman (1986b) before the introduction of TK.

PCK

The views of Mishra and Koehler (2006) were that PCK "represents the blending of content and pedagogy into an understanding of how particular aspects of subject matter are organized, adapted, and represented for instruction" (p. 1021). They argued that, despite various interpretations of PK, CK and PCK, Shulman's beliefs that this intersection provides "ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986b, p. 9) provide the necessary understanding of teacher knowledge and how it relates to practice.

Graham (2011) stated that, "because PCK is foundational to the TPACK framework, researchers must clearly understand PCK before they can productively understand and effectively measure TPACK constructs" (p. 7). The magnitude of teachers developing strong PCK was echoed by Park and Oliver (2008), who said that having such knowledge "distinguishes novice from expert teachers" (p. 262). Despite these assertions on the significance of PCK, there have been questions raised on the practical worth of PCK; for example, it "tends to invoke arguments around the so-called 'theory–practice divide'" (Berry et al., 2008, p. 1273); it is "more of a theoretical argument than a practical one" (Lederman & Gess-Newsome, 1992, p. 19). Many of the issues raised about PCK have been debated long before the arrival of the TPACK framework. This is summarised in the next paragraph.

Berry et al. (2008) featured Shulman's interviews from 1986 and 1987 as a means of supporting their views that Shulman's intentions were for PCK to be of a "generative nature" (p. 1277) where researchers could look "at supervision differently … at assessment differently". PCK was one way of opening up new possibilities for looking into, and better understanding the skills, knowledge and ability of expert teachers" (p. 1277). From all Shulman's work on knowledge, PCK generated the most interest from researchers; However, Shulman maintained that, despite its significance, PCK was only one element of teachers' knowledge.

Van Driel et al. (1998) depicted many examples in research where Shulman's (1986a, 1986b, 1987) work were reinterpreted to try to understand PCK. Of these examples, Grossman (1990) was featured heavily. She found that trainee teachers who had taken part in programs at university that prepared them for the teaching of their subject developed greater PCK than those who were not in such programs. The programs enabled these teachers to appreciate students' difficulties in understanding what was being taught and adjust their practice accordingly. Hence, portraying the significance of developing PCK as part of professional learning teachers should undertake, a point reinforced by Loughran et al. (2012).

Grossman (1990) went on to reinterpret all of Shulman's work. Grossman's descriptions of PCK were highlighted by Aguirre et al. (2013), who described PCK as being made up of:

> 1) An overarching knowledge and belief about teaching a subject at specific grade levels; 2) Knowledge of students' understandings, conceptions, and potential misunderstandings of particular topics of a subject; 3) Knowledge of curriculum and curricular materials, including horizontal and vertical directions within a subject; 4) knowledge of the instructional strategies and representations for teaching particular topics. (p. 115)

The impact of the research of Grossman (1990) can be seen in that, at the time of writing this thesis, it has had approximately 4000 citations since being published. However, given the generative nature of PCK, Grossman's was not the only re-interpretation of Shulman (1987), and Grossman's research has, itself, been further developed. These points will now be discussed.

Looking at the teaching of mathematics, Marks (1990) extended on Shulman's work with the inclusion of knowledge of media for instruction in the subject matter. Magnusson et al. (1999) built upon both Grossman (1990) and Marks (1990), with the additional focus on assessment of knowledge and beliefs. Although not as popular as Grossman (1990), according to Google Scholar, at the time of writing, Marks (1990) has been cited 1096 times and Magnusson et al. (1999) has been cited 3107 times. Clearly, all of these research papers have influenced other researchers in understanding PCK. However, despite their influence and the way they have led to subject-related PCK developments, according to Loughran et al. (2012), there remains, "general 'fuzziness' of the concept" (p. 11) and "some examples of PCK appear to carry little resemblance to the construct as initially conceived by Shulman" (p. 11).

Shulman (1986a, 1986b, 1987) envisaged researchers taking the concept of PCK and further developing it to enable understanding of how to "distinguish the understanding of the content specialist from that of the pedagogue" (Shulman, 1987, p. 8). He wanted to provide established and trainee teachers with, "their own special form of professional understanding … the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organised, represented and adapted to the diverse interests and abilities of learners" (Shulman, 1987, p.8). The remarks of Loughran et al. (2012) suggest that, in their view, 25 years on from Shulman's comments, this has not really happened, and the questions raised on the practical worth of PCK by the likes of Berry et al. (2008) and Lederman and Gess-Newsome (1992) cited earlier remain.

Some researchers have stated that PCK should be treated as subject specific (Loughran et al., 2012; Magnusson et al., 1999; Nilsson, 2008; Van Driel & Berry, 2012). Loughran et al. (2012) and Berry (2012) extended PCK to be both person and situation specific in their research. Gess-Newsome (1999) discussed how the approaches of researchers such as Magnusson et al. (1999) are transformative, where PCK occurs through a synthesis of knowledge Gess-Newsome went on to describe an alternative model for teacher knowledge with an integrative approach. With this approach, PCK would not exist as a specific domain

of knowledge. Instead, it is developed through the intersections it has with subject matter knowledge, pedagogical knowledge and contextual knowledge. However, other researchers (e.g., Bertram & Loughran, 2012; Borowski et al., 2011; Kind, 2009; Nilsson & Loughran, 2012) have debated the merits of these different approaches, and there seems to be no consensus regarding the most effective approach.

It is clear that the literature on PCK suggests it is a complex area. Park and Oliver (2008) stated that, "it has been difficult to portray a clear picture not only of how to scaffold PCK development in teachers but also of how to assess it once constructed" (p. 262). This highlights the overriding difficulties in knowing how to develop PCK and how to evaluate it. According to Graham (2011), difficulties in application and "imprecise definitions of PCK" (p. 7) are a "barrier to measurement" (p. 7). However, as cited earlier, Graham (2011) stressed the significance in understanding PCK as a precursor to understanding TPACK. The lack of precision in definitions that Graham highlighted is also a factor in TCK, where S. Cox (2008) stated that at the time of her writing, there were "13 definitions of TPACK" (p. 38). Graham noted that these definitions were "distinct" (p. 10). Given this, the next section will offer a review of literature on TCK that not only explains the TCK constituent of the TPACK framework but also provides a critical review of definition, understanding and application.

TCK

Mishra and Koehler (2006) stated that, "Technological content knowledge (TCK) is knowledge about the manner in which technology and content are reciprocally related" (p. 1028). This reciprocal relationship relates to "the manner in which technology and content influence and constrain one another" (Harris et al., 2009, p. 399). Thus, understanding this relationship requires an appreciation of how "subject matter can be changed by the application of technology" (Mishra & Koehler, 2006, p. 1028). As Harris et al. (2009) described, there are multiple ways "in which technology and content have related to one another" (p. 400), and advancements in technology suggest that these relationships will continue to develop.

S. Cox (2008) scrutinised the relationship between content and technology in depth. While supporting the views already cited by Mishra and Koehler (2006) and Harris et al. (2009), S. Cox revealed issues in interpretation and definition of TCK, particularly around pedagogy, stating that the involvement of pedagogy in TCK is a concerning issue and its involvement blurs the boundaries between TCK and TPACK. S. Cox also revealed issues with understanding the relationship between content and technology defined by Mishra and Koehler (2006). S. Cox offered a new definition for TCK: "an understanding of the technologies that may be utilized in a given discipline and how the use of those technologies transforms the content of that discipline through representation or the generation of new content" (p. 40). As my research centres on the teaching of a particular technology and how teachers' knowledge and practice are influenced in respect of being able to teach the application of that technology, S. Cox's definition is significant.

S. Cox (2008) went as far as questioning the existence of TCK as a distinct form of knowledge when applying TPACK, questioning "whether or not TCK can, in fact, exist in an educational context." (p. 41). Support for this can be seen in Robertson (2008) and in data collected from 27 Canadian schools by Hofer and Harris (2012). The research by Hofer and Harris concentrated on experienced teachers, and in their analysis of papers in this area, they highlighted that the majority revealed "development of the teachers' TPK was more prevalent than growth in their TCK" (p. 4705). This was supported by Ching et al. (2016) in research based on case studies conducted in an American university; they found that, "teachers' TPK was more obvious and frequently documented when compared with content related knowledge" (p. 118). Hence, there is an argument that when applying TPACK, researchers or indeed teachers who self-report on their TPACK development rarely refer to TCK without mentioning pedagogy. A variety of possible reasons for this dominance of TPK over TCK were suggested by Hofer and Harris. These related to how professional learning typically focuses on TPK; curriculum usually extends beyond content to construct therefore teachers may include their technological content knowledge within curriculum knowledge; TCK is in

fact a sub-domain of TPK in that it is within the application, the practice of the teacher that it develops; teachers may have a lack of knowledge of technology available to develop their TCK.

The last reason given in Hofer and Harris (2012) for the dominance of TPK over TCK relating to teachers' lack of knowledge of technology available to develop their TCK seems to be extended upon in another research paper involving Hofer. In this it was stated that, "another way to understand TCK is that it represents the knowledge required to identify and select technology tools and resources in a particular content area." (Hofer & Grandgenett, 2012, p. 85). Redmond and Peled (2015) supported the views of Hofer and Grandgenett. Hence, there seems to be different interpretations of TCK. It may offer more clarification for researchers and teachers to be able to identify where TCK has been individually developed. Reviewing literature on TPACK has highlighted how, at present, TPK seems to dominate TPACK research papers as an individual construct; hence, it is the focus of the next section.

TPK

In the same way that TCK involves a reciprocal relationship between technology and content, TPK features a similar relationship but in respect of technology and pedagogy. This relationship can be seen to some degree in the definition of TPK offered by Mishra and Koehler (2006): "Technological pedagogical knowledge (TPK) is knowledge of the existence, components, and capabilities of various technologies as they are used in teaching and learning settings, and conversely, knowing how teaching might change as the result of using particular technologies" (p. 1028). However, it is much clearer in Koehler, Mishra, and Cain (2013), according to whom TPK includes "knowing the pedagogical affordances and constraints of a range of technological tools as they relate to disciplinarily and developmentally appropriate pedagogical designs and strategies" (p. 16).

Further scrutiny of the definitions of TPK from Mishra and Koehler (2006) and from Koehler, Mishra, & Cain (2013) also suggests that TPK is intended to be applied in the

planning stages as well as in actual teaching practice. Developing TPK requires "a deeper understanding of the constraints and affordances of technologies and the disciplinary contexts within which they function is needed" (Koehler, Mishra, & Cain, 2013, p. 16). Hence, TPK refers to a relatively in-depth knowledge of technology tools and the possibilities they offer in terms of plans for and practice in specific disciplines. Developing TPK not only requires understanding of the way technology and pedagogy mutually afford and constrain one another but also how and where they can be applied in practice.

Koehler, Mishra, and Cain (2013) described how TPK's significance in developing TPACK stems from the need for adapting "software programs that are not designed for educational purposes" (p. 17) but they are usually designed with business in mind. The effect of this is that "TPK requires a forward-looking, creative, and open-minded seeking of technology use, not for its own sake but for the sake of advancing student learning and understanding" (Koehler, Mishra, & Cain, 2013, p. 17). Such views have been cited and used to argue that those teachers who are strong at integrating technology not only "need some level of technological expertise or knowledge but also need to be life-long learners who are willing to experiment and take risks" (Mueller & Wood, 2012, p. 11). Thus, this supports the view that "teacher attitude and beliefs are key to successful technology integration" (Cydis, 2015, p. 70). The attitudes and beliefs of teachers are a focus of my research; hence, TPK will feature prominently as a discussion point in this respect.

The significance of TPK can be seen not only in the way that its presence and development enhance planning and practice but also in the way its absence has a negative effect. Figg and Jaipal (2009) and Hosseini and Kamal (2013) posited that a lack of TPK negatively affects a teacher's TPACK and in turn the ability to integrate technology in their practice. In further research, Jaipal and Figg (2010) highlighted the potential consequences of teachers lacking in TPK providing a catalyst to identifying the essential characteristics of TPK and providing specific training to pre-service teachers They insisted that such training needs to ensure teachers entering the profession have instructional design skills. These skills

would enable them in the planning element of TPK and equip them with the skills for implementation when using technology in their discipline areas. If this view is supported, there is an implication that the same or similar professional learning could be beneficial for practising teachers, as proposed in Koh (2019).

Despite the significance of TPK in TPACK research and the number of papers that attempt to unpack this TPACK construct, issues remain with its definition and interpretation. S. Cox (2008) identified "10 definitions of TPK in the selected resources" (p. 41). She went on to highlight how in her research, participants did not "agree on what exactly TPK is or whether a teacher could have pure TPK without injecting content." (p. 61). In other words, she pointed to a lack of distinction between TCK and TPK common in research studies.

Referencing the work of S. Cox (2008) and the points discussed above on TPK and earlier in TCK and PCK, Graham (2011) called for improvements in TPACK research in these areas. Hofer and Harris (2012) highlighted issues in identifying instances where teachers exhibit the specific constructs of TPK and TCK, or similarly those of PCK. Following their advice, I aim to deploy "more focused interview prompts … and more effective data analysis techniques" (Hofer & Harris, 2012, p. 4707) to ensure the TPACK framework is applied properly.

TPACK

Taking what Gess-Newsome (1999) would describe as a transformative perspective, TPACK was introduced by Mishra and Koehler (2006) as a form of knowledge "that goes beyond all three components (content, pedagogy, and technology)" (p. 1028). It is a focus on the intersection of all three knowledge constructs; in other words, where they come together to produce a form a knowledge which is "the basis of good teaching with technology" (Mishra & Koehler, 2006, p. 1028). This form of knowledge is an "understanding that emerges from interactions among content, pedagogy, and technology knowledge (Koehler & Mishra, 2009, p. 66). Thus, it refers to the understanding that teachers have that is not solely about content or pedagogy or technology but all three combined.

TPACK is not a static form of knowledge. It is dynamic and flexible (Doering et al., 2009; Koehler & Mishra, 2009; Mishra & Koehler, 2006; Niess, 2011). Dynamism and flexibility relate to how "new technologies emerge for integration into particular content areas" (Niess, 2011, p. 307), highlighting the continual evolvement in technology and how these technologies have the potential for use in education in particular ways and in specific disciplines that may have an effect on pedagogy. In relation to the TPACK framework as a whole, "teaching successfully with technology requires continually creating, maintaining, and re-establishing a dynamic equilibrium among all components" (Koehler & Mishra, 2009, p. 67). Their observation was that the forms of knowledge that need developing to achieve TPACK change continually based on the content being taught, how best to teach that content and the technology being used. This relationship is not linear, though. Any of the constructs can and do change in teaching practice, hence the need for a "dynamic equilibrium" of the components.

S. Cox (2008) saw such terms as *dynamic* and *flexible* in descriptions of TPACK as evidence of the framework's complexity: Thus, it is apparent that, in order for one to possess TPACK, first, one must possess each of the knowledge types, and second, one must understand the intricacy of the relationship between those domains. She alluded to the need to balance the forms of knowledge in the TPACK framework. This echoes Mishra and Koehler's (2006) sentiment:

> Teaching and learning with technology exist in a dynamic transactional relationship (Bruce, 1997; Dewey & Bentley, 1949; Long, 1981) between the three components in our framework; a change in any one of the factors has to be "compensated" by changes in the other two". (p. 1030)

In other words, there are many factors at play, and the knowledge constructs are dependent on those factors and the interactions between them. With such a fluid environment, there is the need to understand the circumstances that form TPACK knowledge, in other words, the context. How TPACK will be different given technology, pedagogy and content factors are discussed in Section 2.1. (Knowledge use and context in TPACK) below.

Additionally, having TPACK is having knowledge on many levels, according to S. Cox (2008). Teachers must not only have knowledge of the individual constructs but also how they relate to each other. As the TPACK framework examines "the kind of knowledge teachers need to integrate technology in their teaching practices." (Voogt & McKenney, 2017, p. 70) and has been applied in many teaching situations to look at teacher knowledge and practice, it is a highly relevant framework in answering my research question. However, as shown in this literature review thus far, in applications of the TPACK model, its individual constructs and the intersections, difficulties in interpreting knowledge are common. What has not been discussed to this point in the literature review, however, is the question of how knowledge is developed.

While recognising many of the issues in interpretation discussed in this literature review, M. Phillips et al. (2017) sought to analyse the different TPACK knowledge forms focusing on epistemology. Their broader stance on the significance of understanding the nature and meaning of knowledge in TPACK research provides a perspective by which to look at the knowledge more holistically and with more intricacy. In doing so, this research study can look to better understand how SDLs can influence teachers' knowledge. This will be a springboard into looking at how knowledge is developed.

All the research examined in the sections above seems to regard knowledge development to be individual. In other words, they have considered TPACK to be forms of knowledge that a teacher is expected to have to integrate technology. However, there is literature that questions such assumptions and views, considering that developing knowledge may come from elsewhere. Hence, the source and holder of knowledge elements of the TPACK framework may not be the teacher who is attempting to integrate technology. This is highly significant, given that this research features team teaching and that the focus is on how SDLs can influence the teachers. The students who feature in the SDL roles all have their own knowledge and the potential to influence teachers in this study, to influence what happens when teachers use technology in their practice. Given this, the next section will discuss how

knowledge can be seen as beyond that of the individual in TPACK literature.

Knowledge development in TPACK

According to Di Blas, Paolini, et al. (2014), there is consensus in research that TPACK is "a form of knowledge that is resident in the heads of individual teachers" (p. 2457). However, Nore et al. (2010) challenged this notion stating that, "there are challenges beyond the model's individual-oriented focus" (p. 3921). In many ways, Nore et al.'s work seemed to align with the learning design model suggested by Mishra and Koehler (2006), but there was a clear statement of intent in Nore et al.'s report in that they based analysis of the 5-year development of learning networks on the shared experiences of the participants. Their statement that "TPACK becomes shared and distributed" (p. 3922) seems to have prompted a shift in focus to questions of who has knowledge and whether it is, or should be, held by an individual in teaching contexts.

Despite not citing Nore et al. (2010), Di Blas, Paolini, et al. (2014, p. 2457) provided an outright challenge to individual knowledge and suggested that TPACK is often distributed. The basis of their challenge was:

> Teachers typically surround themselves with a network of support that includes other teachers, teacher's edition of textbooks, instructional websites, technology experts, and students. The knowledge that each of these individuals and artifacts possess needs to be understood by the teachers and shared with them for the teaching with technology task to be successful.

Thus, the way teachers work, the ecosystem that they work in are a basis for seeing knowledge as distributed rather than individual. In other words, teachers do not work in isolation. They are influenced directly and indirectly by a "network of support" (Di Blas, Paolini, et al., 2014, p. 2457). Hence, the research of Di Blas, Paolini, et al. highlighted the view that there are more factors that go into teaching than just the teacher's knowledge, which provides a different perspective on what exactly the elements of TPACK can be.

Seeing their work "as being an important advancement of the TPACK framework that has

significant implications for how we look at future research in the area" (p. 2458), Di Blas, Paolini, et al. (2014) focused on Koehler et al.'s (2007) and Benson and Ward's (2013) work. They used these two papers to highlight questions of where knowledge comes from, how it develops in teachers. While stressing that the majority of applications of TPACK in research studies focused on individual knowledge, they highlighted suggestions in research that distributed knowledge was already in effect but had not been recognised including work they were involved with in Italy.

At the time of writing this literature review, there appears to be a growing amount of research in diverse geographical locations and in various education sectors supporting the concept of distributed knowledge. Examples include a Tanzanian study in a secondary school (Kihoza, 2016); a study into the use of TPACK for professional learning across school districts and schools in America (Harris & Hofer, 2017); a Norwegian study on the use of iPads in primary schools (Engen et al., 2014); and a paper looking at educators' reflections on the integration of digital textbooks in higher education in Australia (Smith, 2017).

One particular research study, by Jones et al. (2015), used distributed knowledge, which they described as TPACK shared practice, to analyse the contributions of teacher educators using a shared blog during a teaching year. The arguments they provided were that the "knowledge required is situated, distributed and social" (p. 3293). The educators demonstrated distributed knowledge. They overcame problems in the systems and technology they worked with through the knowledge of their peers, through social interactions in a blog working with situations relevant to their context. The use of a blog provided a setting to enable the sharing of knowledge between teacher educators, a space for collaboration and dialogue to enhance their TPACK.

A specific idea mooted in Jones et al. (2015) is that "with digital technologies it is possible and desirable that we shape our technologies, then our technologies shape us, and then – as we learn – we shape our technologies some more." (p. 3289). Jones et al. suggested that,

given its protean nature, TK is subject to rapid change. Unlike with pedagogy and content, technology develops quickly and, often, new knowledge is required alongside these developments. Looking back to the introduction of the TPACK framework, Mishra and Koehler (2006) said that TK "requires a detailed understanding of complex relationships" (p. 1018). Jones et al. (2015) seemed to be arguing that the protean nature of technology is one of the causes of those complexities. M. Phillips et al. (2017) highlighted the complexities in TK by explaining how knowledge can be on a sliding scale from episteme to phronesis and that each form of knowledge can have a different position on that scale.

There are some correlations between the views of Jones et al. (2015) and those of M. Phillips et al. (2017). For example, TK is subject to "constant and rapid change" (Jones et al., 2015, p. 3289), where teachers need "knowledge of how to leverage the protean nature of digital technologies" (p. 3293). Hence, there are often situations, as described in Jones et al., where teachers do not have some or all of the TK to integrate technology. However, they can gain the knowledge they require through other sources, through distributed means. This has parallels to what M. Phillips et al. (2017) described as phronesis, "a reasonable way to conceive of some of the knowledge that expert teachers draw on to inform their practice" (p. 2427). Furthermore, in many ways, these views support those discussed in Section 2.1 above; the idea that integrating technology involves how people relate to the technology and how they use it (Cooke, 2012; Okojie, 2006).

In answering the research question posed in this thesis, the work of M. Phillips et al. (2017) is relevant in that it prompted me, as a researcher, to "step back and clarify what is meant by the term 'knowledge'" (p. 2427) during discussions on findings. M. Phillips et al. argued that there would be implications from such clarification of knowledge, and two in particular are considered relevant to my research. These are "to better understand the forms of knowledge that expert teachers use as part of their classroom technology integration" and to "better understand the effective technology practices" (p. 2427) of teachers who integrate technology successfully.

The issue of what teacher knowledge is, is not a central focus of this thesis, whereas distributed knowledge is. Seeing knowledge as distributed in application of TPACK, as the likes of Nore et al. (2010), Di Blas, Paolini, et al. (2014), Di Blas, Fiore, et al. (2014) and Jones et al. (2015) have, is a key element in answering the research question presented. Given the aim of my research is to understand if teachers' knowledge and practice with digital technology can be influenced through increasing the active involvement of students in the technology integration process, acknowledging the concept of distributed knowledge plays an important role. Understanding teachers' knowledge and practice and whether they are being influenced requires a clear appreciation of where knowledge is being shown and who it is shown by. This may be on a shared or an individual basis. However, despite their significance in shifting thinking on knowledge in TPACK, arguably the most important issue that papers on distributed knowledge highlight in respect of my research question, is that there does not seem to be any study into exactly what happens when TPACK knowledge is shared with students. Evidence of this can be seen through searches of education databases detailed in Appendix A.

Looking again at Nore et al. (2010) in relation to sharing knowledge with students, "students are digital learners and used to more collective ways of thinking and learning, and are familiar to knowledge building across borders" (p. 3920). This statement reveals the authors' beliefs that student knowledge is often distributed and influenced by more exposure to digital learning. They also proposed that, "the physical space of learning is expanded with a new virtual learning space where both students and teachers become parts of more collaborative knowledge building" (p. 3920), positioning teachers and students as building knowledge together enabled by technology. Lastly, in the paper's conclusion, there is recognition that "school development can emerge from discussions between students, teachers and managers" (p. 3922), again pointing out the significance of having students involved in influencing education developments.

At the time of writing, Nore et al. (2010) had been cited 15 times, and of those, Di Blas and Paolini (2017) provided an interesting insight on how students can affect teachers' knowledge. Table 1 presents some of their findings in looking at distributed and dynamic TPACK and the influences on teacher knowledge where students are seen as an important source of improvement. As is evident in Table 1, "teachers learn from learners" (Di Blas & Paolini, 2017, p. 2314); they went on to describe how this is an aspect of knowledge flow within a dynamic and distributed TPACK experience: TK can flow from teacher to learner and from learner to teacher.

Table 1: *Sources of improvements in TK for the teachers (Di Blas & Paolini, 2017, p. 2313)*

	Not at all	**A little**	**Enough**	**Much**	**Very much**	**Sum of much/very much**
Self-training	1.1%	2.2%	35.5%	32.3%	28.0%	60.3%
My students	21.5%	20.4%	23.7%	21.5%	5.4%	26.9%
Outside help(ers)	34.4%	17.2%	23.7%	15.1%	1.1%	26.9%
Other	22.6%	0.0%	1.1%	4.3%	1.1%	26.9%

Di Blas and Paolini (2017) provided an example in their research where students provided TK to teachers, in other words, where students were sources of improvement in TK for teachers, as depicted in Table 1. Their research relates to an unplanned event with a student showing the teacher how to use an audio recording program, which is highlighted by the researchers as "quite surprising, due to the very young age of the pupil acting as teacher 'trainer'" (p. 2316). Their findings support the views of Nore et al. (2010) in relation to seeing that student knowledge is often distributed and their knowledge comes from greater exposure to digital learning. However, my research was concerned with planned events, having students chosen to work with teachers, to assist with technology integration in their teaching practice. The focus was directly on the effects that students have on teachers, to answer specific questions on what happens to teachers' knowledge and practice when a strategy is implemented to influence teachers in technology integration.

In Di Blas and Paolini (2017), there is clear evidence that knowledge, particularly TK, can be shared with students, expanding the concept of distributed TPACK to describe the dynamic nature of knowledge flows within the framework when students' knowledge flows to the teacher, improving the teacher's TK. However, as they acknowledge, their research was "limited to a very specific experience" (p. 2316) and was carried out under laboratory conditions, which "may have too heavy an influence on the results" (p. 2316). They then go on to say that, "in order to fully understand the distribution and flows of Ks within a complex educational experience, research should be conducted within "real life settings" (i.e. actual learning processes carried on at school)" (p. 2316), which in some ways my research intends to contribute to.

Although Nore et al. (2010) seemed to prompt discussions around knowledge being shared in TPACK research and their study featured insight on the role of students, it was not until Di Blas, Paolini, et al.'s (2014) study that there was a focus on the influence students can have on teacher knowledge. Their research considers the role of students: "the knowledge that each of these individuals … possess needs to be understood by the teachers and shared with them for the teaching with technology task to be successful" (p. 2457). This indicates an acknowledgement that students have knowledge, and that knowledge is not solely held by the teacher, which supports the idea that students have the potential to influence teachers in respect of TPACK. However, Di Blas, Paolini, et al. talked only about the necessity of understanding students' knowledge. They did not talk about deliberately and actively using that knowledge to influence teacher knowledge and practice when using technology.

The work of Di Blas, Paolini, et al. (2014) provided evidence of a teacher deliberately and actively using a student's knowledge to influence their practice when using technology. Akin to my research, they described a teacher who mentioned the following:

> "There is just one boy in the class, and he is very good at computers; so he was the one who moved the avatars in the virtual world all the time." As such, even though teachers did not possess strong Technological Knowledge, they offloaded the technology

> responsibility to others and then continued to successfully implement the programs. (p. 2460)

The teacher's practice appears to be directly influenced by the knowledge and skills of a student. Similarly, in Di Blas and Paolini (2017), a teacher depicted a particular occasion where a student's action in assisting with technology affected teacher practice, although in that example, this seems to have been a one-off. Both of these provide an insight, although brief, to suggest the influential role school students can have in technology integration.

However, it is worth noting that what is being described by Di Blas, Paolini, et al. (2014) and in Di Blas and Paolini (2017) may not be the sharing of knowledge. Having "offloaded the technology responsibility" (Di Blas, Paolini, et al., 2014, p. 2460) to students may mean that the knowledge stays with the student, and in the example of moving the avatars provided in the case study of Di Blas et al. (2014), the teacher does not develop knowledge of how to do this from the student. Likewise, in Di Blas and Paolini (2017), the fact that the student operates the audio software may mean that the teacher is still unable to operate it. Hence, their TK, in this instance, remains the same. Thus, Di Blas, Paolini, et al. (2014) did not discuss whether the evidence in these case studies amounts to sharing knowledge that influences only the practice or the knowledge and practice of the teacher. This is a point that I intended to explore in my research.

The citations from Di Blas, Paolini, et al. (2014) given so far and the event described in respect of the audio recording program in Di Blas and Paolini (2017) could give the impression that having students actively involved in practice were isolated events. This is not the case, though, as Di Blas, Paolini, et al. revealed further instances where teachers actively involved students in their teaching practice, "many relied on …. students themselves to run the experiences" (p. 2460), whereas Di Blas and Paolini provided teacher views that students are a good source of TK (see Table 1). Additionally, the comments by teachers in Di Blas, Paolini, et al. and Di Blas and Paolini alluded to a wider appreciation and utilisation of student knowledge, not just confined to TK, although there was no deep discussion on the

types of knowledge involved or the on the effects they had on teacher knowledge and practice.

Di Blas, Paolini, et al. (2014) conducted a study involving a digital storytelling competition set up for the World Expo in Milan. The majority of participants in the competition were Italian. The topic, environmental sustainability, was not taught in the Italian curriculum at the time, and "most of the teachers did not possess enough prior knowledge regarding the content; and in some cases, the students were more knowledgeable. As such, teachers learned the content together with their students and managed to collectively construct successful learning experiences" (p. 2460). Clearly, students were actively involved in affecting teachers' CK and, possibly, PCK, leading to changes in practice. In other words, there is strong evidence from the Di Blas, Paolini, et al. case studies that knowledge and practice were influenced by active involvement of students in respect of content. However, when knowledge is technological, there may be issues as to whether actively involving students leads to the sharing of TK with the teacher.

Jones et al. (2015) called for further research in some ways related to my research question. They proposed the question "How can TPACK be shared with other teacher educators and their students?" (p. 3293). However, their research, and indeed all the research cited from Di Blas, Paolini, et al. (2014), has been in a university setting, whereas that of Di Blas and Paolini (2017) was carried out under laboratory conditions. There do not seem to be many studies examining the role of secondary school students in influencing teachers' knowledge and practice. Thus, I conducted a search to look for and analyse literature on research in a secondary school setting. I accessed Monash University's education databases with searches on ProQuest Education, ERIC, PsycInfo and A+ Education journals. The search terms used were "shared TPACK"; "shared TPACK" and "high school students"; "shared TPACK" and "secondary school students"; "distributed TPACK" and "high school students"; "distributed TPACK"; "distributed TPACK" and "secondary school students"; "shared TPACK" and "students" and "secondary school"; "distributed TPACK" and "students" and

“high school”. These terms were used to search the full text of journals. A summary of the findings from these searches is provided in the Appendix A.

Looking at the four articles that resulted from the search of education databases for shared or distributed TPACK in a secondary school setting (Appendix A), there do not seem to be any studies on where or how secondary school students influence teachers’ knowledge and practice. The multi-search conducted provided only one result where the research was directly related to Jones et al. (2015)’s call for further research, namely on how TPACK can be shared with other teacher educators and their students. However, the focus in this one paper, Webb (2014), centred on CK and the resulting effects on PCK. The technological factor relates to how students have had their CK increased through access to digital resources, which can then result in subsequent changes to teaching practice. Hence, in looking at TK and TPK being shared with secondary school students and how that influences the knowledge and practice of teachers, my research may provide contributions.

To summarise this section on knowledge development in TPACK: In order to answer the research question *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?* TPACK offers a framework for understanding technology integration while also understanding what teachers need to know and how the elements of knowledge interrelate (Mishra & Koehler, 2006). However, relatively recent developments in TPACK research have suggested that the development of knowledge in TPACK is shared. This provides foundations for suggesting that students have TK which they can share, and this can influence teachers in respect of their TK, possibly even their TPK and TCK.

Knowledge development, the concept of sharing knowledge, and how SDLs can play a role in affecting teachers’ knowledge are clearly significant aspects of this research, and the literature review to this point has considered studies and viewpoints in relation to these. This research is not just concerned with knowledge, however. It is also concerned with practice

where knowledge that has been developed is used in the classroom. Having knowledge and using knowledge in respect of TPACK are two different elements that the framework should be able to represent (Doering et al., 2009). However, Doering et al. also recognised that their views on knowledge use and indeed any analysis of knowledge and practice cannot ignore the issue of context which "influences both teacher knowledge and practice" (p. 336). Likewise, in many of the papers cited in the preceding sections of this literature review on TPACK, the issue of context is directly mentioned or suggested as a factor in understanding and interpreting TPACK. Hence, the next section will explore the idea of having knowledge and using knowledge, which will lead into the influence of context and its wider relevance in TPACK research.

Knowledge use and context in TPACK

Doering et al. (2009) saw limitations in the TPACK framework, describing situations where "uses of a teachers' knowledge depend on the context of a specific situation – be it a specific classroom or a specific lesson" (p. 336). M. Phillips (2015) described how a teacher may use specific technologies in one lesson but choose a completely different approach in another lesson: "it is unlikely that the teachers' TPACK has varied moving from one room to another, but her enactment of her TPACK has varied dramatically" (pp. 330). He labelled situations such as the example he provided as "changes in context" (p. 330) and how these "changes" highlight that there are "factors influencing effective integration of digital technologies beyond simple binary choices of adoption and non-adoption" (p. 330).

Brantley-Dias and Ertmer (2013, p. 115) said:

> A number of other factors must be considered and/or addressed to enable teachers to "teach effectively with technology," including factors both internal (e.g., pedagogical beliefs, confidence, attitudes) and external (e.g., school and classroom cultures, school and district policies) to the teacher.

This clearly delineates between "internal" and "external" influences on teachers trying to integrate knowledge and relates back to the discussions on the complexities in trying to

achieve successful technology integration (Section 2.1). However, Brantley-Dias and Ertmer did not indicate which, if any, of these factors they considered to be context and which they did not, despite mentioning context 16 times in their paper and stating it as "fact that TPACK is very context specific" (p. 118).

Hence, from the work of Doering et al. (2009) and Brantley-Dias and Ertmer (2013), there is a clear argument for the influence of context on teacher knowledge becoming practice. This is supported by the recognition that assumptions should not be made "that all teachers teach the same way and hence would use technology the same way" (Mishra & Koehler, 2006, p. 1032), which relates directly to my research study as it will analyse a number of teachers, their knowledge and practice in different situations.

Seeing context "as an interactive system" (Jones et al., 2015, p. 3288) draws attention to its reciprocal nature and how it incorporates factors that affect a teacher and that the teacher effects. However, many researchers have highlighted that there are issues with lack of clarity in and problems in the definition, interpretation and understanding of the real meaning of context in TPACK research (S. Cox, 2008; Jones et al., 2015; M. Phillips, 2015; M. D. Phillips, 2014). Similar issues have been described in respect of understanding context outside of TPACK research (Abowd et al., 1999; Bazire & Brézillon, 2005; Burke, 2002).

More recently, in TPACK literature, much attention has been given to the work of Porras-Hernández and Salinas-Amescua (2013). Although they recognised the effectiveness of the TPACK framework in improving how teachers use technology in their practice, their work identified issues with the model. The first of these was that "the original TPACK framework … defines the contexts in which teachers work too narrowly" (p. 224). They then added that research using the TPACK framework succeeds only in being too generalist for the most part.

Porras-Hernández and Salinas-Amescua (2013) sought to address the confines of the original definition of context in TPACK and the lack of clarity in research application by highlighting complexities in understanding and applying context. This led to their suggestion

that context can be separated as "Scope: Macro, meso, and micro level contexts; and…Actor: Students' and teachers' contexts" (p. 228). The idea of "scope" and seeing context in these three distinct levels aligns with the context discussion in management research in Bamberger (2008) cited earlier. However, the essential difference between Porras-Hernández and Salinas-Amescua and Bamberger is that, despite the same use of levels, in TPACK, the concern is knowledge. Porras-Hernández and Salinas-Amescua saw context as "not only externally given conditions that influence or determine teachers' practice, but also objects of knowledge that the teacher learns to interpret" (p. 228). Hence, there was somewhat of a realignment, a refocusing in research by Porras-Hernández and Salinas-Amescua to the fact that TPACK research, including the outer circle of the framework, is about knowledge. Given this, application of TPACK requires answering questions on what teachers know at the three contextual levels and how that influences them in integrating technology into their practice.

The contextual levels described by Porras-Hernández and Salinas-Amescua (2013) included quite clear delineations with the macro level including "social, political, technological, and economic conditions" (p. 228); the meso level as the perspectives of "schools and principals and superintendents" (p. 228); and the micro context level as "concerned with in-class conditions for learning" (p. 230). In many ways, Porras-Hernández and Salinas-Amescua moved the context element of the TPACK framework on from largely concentrating on classroom, pedagogical and technological components of knowledge as seen in, for example, Mishra and Koehler (2008). This provided much wider scope for the influence of context in TPACK.

It could be argued, however, that with such a broad range of factors that make up context in the descriptions of Porras-Hernández and Salinas-Amescua (2013), previous discussions on the difficulties in determining what is influential and what is not become even more problematic. In other words, it would seem that the views of Turner and Meyer (2000) and Burke (2002) leading to the question cited earlier in respect of contextual factors, "How does one choose those which are relevant to the design challenge at hand?" (Mor, 2011, p. 2016)

becomes even trickier to answer. The solution, according to Porras-Hernández and Salinas-Amescua, seems to rely on interpretation. When applying the TPACK framework to research situations, the important consideration is in determining "objects of knowledge that the teacher learns to interpret" (p. 228). Thus, whether a contextual factor becomes part of a teacher's knowledge comes down not only to their awareness of its existence but also in how they interpret it.

Porras-Hernández and Salinas-Amescua (2013) provided examples of government initiatives, the availability of training and provision of information technology equipment as the macro context. They went on to say:

> All of the teachers in our study participated in these programs. The teachers seemed to be well aware of the conditions under which ICT could be successfully integrated in their schools, and they were also cognizant of the fact that most human activities required the use of ICT. (p. 228)

This quote highlights how the teachers involved in their research study had exposure to the macro-level context described. However, what is not clear is whether knowledge of the training programs and the fact that the equipment was provided by the government would in itself amount to context at this level or whether participation in the events is necessary. Exploring further research where Porras-Hernández and Salinas-Amescua (2013) are mentioned does not really clarify this point, and as highlighted by Ervin-Kassab (2014), such consideration of context levels in research remains relatively new.

In applying the levels of context proposed by Porras-Hernández and Salinas-Amescua (2013), Blackwell et al. (2016) stated that they were not featuring the macro context level. Despite opening their paper by setting the scene of how tablet computers have become so popular in early childhood education using examples of societal, governmental and institutional influences, their focus was on the meso and micro levels. Swallow and Olofson (2017) considered all three levels of context but found that "larger institutional or societal elements of context did not influence TPACK to a similar extent" (p. 239). Furthermore, later,

in the same paper, they stated, “our findings suggested that macro elements of context, in which teaching, learning, and institutions are embedded, do not function in a direct way upon TPACK development” (p. 240). This latter statement seemingly undermines the significance of context at the macro level in the TPACK framework and, it could be argued, is in stark contrast to how Porras-Hernández and Salinas-Amescua see the situation in their research.

On their analysis on TPACK publications, Rosenberg and Koehler (2015) found macro factors included in only 14% of the papers they analysed, compared to meso factors at 61% and micro factors at 84%. Swallow and Olofson (2017) said that macro factors of context influence only teachers’ TPACK development indirectly and that these come through the meso and micro levels. Given the findings of Rosenberg and Koehler, the views of Swallow and Olofson and how Blackwell et al. (2016) chose not to consider context at the macro level, my research will not delve deep in these areas of context. Macro contextual factors will feature only where they are seen as influential to a teacher’s knowledge and practice in technology integration in the classroom.

The meso level, those elements of context that are at a school-wide or community level, was the focus of Harris and Hofer (2014). Their research concentrated on “how the TPACK construct was reinterpreted – specifically, appropriated and reconceptualized – by the 12 participating school- and district-based professional development providers to fit the meso-level contexts (Porras-Hernandez & Salinas-Amescua, 2013) within which they work” (p. 2521). In other words, the meso contextual level was the basis of their research. This highlights the significance of these elements of context. Hence, my research involved the senior leaders of the school, whole-school foci and any in-school cultural factors that are relevant to technology integration and to the concept of student SDLs.

Some researchers seem to have suggest that the micro levels of context were prevalent features of TPACK research prior to the definitions of levels provided by Porras-Hernández and Salinas-Amescua (2013). This can be seen in Koh et al. (2014), where they referred to

Zhao et al. (2002) demonstrating micro-level factors as influential in their research. Rosenberg and Koehler (2018) provided examples of TPACK research where those micro-level contextual elements were featured: Kelly (2008) and Banister and Reinhart (2011). In addition, given that "micro is the most proximal context for learning and development" (Rosenberg & Koehler, 2018, p. 448), it is perhaps unsurprising that factors at the micro level of context are prominent in literature where Porras-Hernández and Salinas-Amescua (2013) have been referenced. Swallow and Olofson (2017) collected data at the micro level that "inquired about teachers' backgrounds, personal technology use, and educational values" (p. 232). As my research study was very much centred on teachers and how they are influenced by SDLs in knowledge and practice using technology in classroom situations, I took similar approaches.

What has been discussed thus far in relation to Porras-Hernández and Salinas-Amescua (2013) has focused on what they termed as "scope". However, this was only one of two halves of context that they described. The other half concerned students and teachers, whom they labelled as "actors" and described how they should "become objects of knowledge with their unique inner and external contexts" (p. 231). According to Swallow and Olofson (2017), they become contextual factors that need to be considered in TPACK research as they "shape not only their actions but also the educational processes, as teachers respond to these elements" (p. 231).

Porras-Hernández and Salinas-Amescua (2013) acknowledged that there has already been much written in research on factors such as "students' previous knowledge, attitudes, preconceptions, and interests" (p. 231), labelling these as inner contexts. They then proposed that there are also external factors, those influences on students that ultimately become part of TPACK context in the definition proposed in their research. Providing an example of something that sparked a student's interest in learning, they depicted external contexts as those parts of a student's daily life that influence their attitude to learning.

As well as the inner contexts and external factors, Porras-Hernández and Salinas-Amescua (2013) described "teacher's subjective variables are also factors that can explain not only technology integration, but also the knowledge construction that takes place in a given situation" as influences on TPACK for students (p. 233). Rosenberg and Koehler (2018) interpreted these "teacher variables" as "involving all teacher characteristics (such as their beliefs, motivations, and other factors) except their TPACK" (p. 446). Porras-Hernández and Salinas-Amescua cited Ertmer and Ottenbreit-Leftwich (2010) in examples of the variables that can affect a teacher's context. Ertmer and Ottenbreit-Leftwich centred their paper on teachers being agents of change and how teacher's self-efficacy, self-confidence and attitudes to their role, particularly in regards to technology integration, determine its success. Such suggestions give credence to the concept of teachers as actors and the degree of influence the factors described may have on their TPACK.

Swallow and Olofson (2017) considered context using the approach detailed in Porras-Hernández and Salinas-Amescua (2013). Their findings suggest that, despite the significance of Porras-Hernández and Salinas-Amescua's work in respect of context in TPACK, there are still areas of contention. Swallow and Olofson "found the influential components of context to be primarily specific to the teacher actor at the micro or classroom-level context" (p. 239). This seems to support the earlier argument regarding macro-level influence provided by Rosenberg and Koehler (2015) but it goes further in suggesting that meso level factors may also not be influential.

The context framework described by Porras-Hernández and Salinas-Amescua (2013) was at the centre of discussions in Rosenberg and Koehler (2015). They considered the components of scope and actor as a means by which "knowledge of context and knowledge in-context" (p. 448) can both be considered as context. In their findings, Rosenberg and Koehler recommended not only greater inclusion of context in TPACK research but also that researchers look at how each of these versions are developed by teachers in technology integration.

Some of the methods, in particular the wording in the coding frames of Rosenberg and Koehler (2015), were the subject of criticism by M. Phillips (2017), who argued that the way they categorised the levels of context has the potential to create more difficulties for TPACK researchers. Likewise, M. Phillips suggested that the work of Rosenberg and Koehler needs developing in respect of how context describes conditions. M. Phillips stated that, "'conditions around the knowledge and activities' may be enhanced by further consideration and refinement" (p. 1774). He recommended that TPACK should always be measured, "considering the socially mediated context in which TPACK is enacted" (pp. 1792 & 1793) and that context includes practice and identity. The issue of identity and how it linked to my research will be discussed in Section 2.2 (Literature review conclusion), but the inclusion of the views of M. Phillips in this regard is intended to outline that although the context framework introduced by Porras-Hernández and Salinas-Amescua (2013) was significant in the approach I took in my research, there remain other factors in respect of context to discuss.

To close this section of the literature review on context, it is worth highlighting that at the time of writing, an "upgrade" has recently been suggested by Mishra (2019) to the TPACK framework in respect of contextual knowledge:

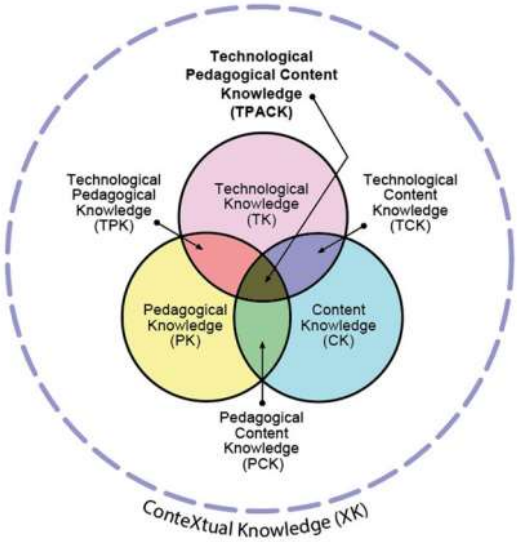

Figure 2: Revised version of the TPACK image. © Punya Mishra, 2019. Reproduced with permission

Mishra (2019) relabelled the outer circle of the diagram to include the word "knowledge" saying that in its previous form, it was "not designated as a form of knowledge" (p. 76). He then went on to say:

> There is an added benefit to this move to Contextual Knowledge. This makes the outer circle another knowledge domain that teachers must possess to integrate technology in teaching. This, in turn, implies that contextual knowledge is something that we (as teacher educators) can act on, change, and help teachers develop. (p. 76)

Such recognition of the significance in seeing context as a knowledge construct within the TPACK framework reiterates calls in literature already cited, for recognition of its significance and its influence in TPACK. This also reinforces the inclusion of context knowledge as an essential form of teacher knowledge and its subsequent inclusion in the knowledge base proposed by Shulman (1987).

The suggestion from Mishra (2019) that referring to contextual knowledge in TPACK as XK relates to the fact that "contextual knowledge often is highly variable" (p. 77) seems to lend support to previous discussions in this section on how considerations of context are in themselves highly contextual and support the view that there are a multitude of factors that affect a teacher's decision to integrate technology or not (M. Phillips, 2015). Mishra's additional explanation for using XK, that it "allows us to go beyond seeing teachers as designers of curriculum within their classrooms but rather as intrapreneurs – knowing how their organization functions, and how levers of power and influence can effect sustainable change" (p. 77), seems to elevate the status of context even further. In respect of my research, the views of Mishra (2019) support consideration of any evidence where teachers show they know how the school, and perhaps the education authorities beyond the school, see their work with SDLs and technology integration and their own thoughts on the ongoing significance of such work. On the contrary, there may be evidence where teachers show they do not possess such knowledge or do not regard the work with such high esteem, allowing some teachers to be seen as "designers of curriculum within their classrooms" (Mishra, 2019, p. 77). In summary, at the core of Porras-Hernández and Salinas-Amescua (2013) was their view that,

until that point there was a "predominant use of TPACK in a prescriptive manner for assessing teacher-training interventions designed for technology integration and oriented by a deductive perspective" (p. 224). Their desire to "generate knowledge inductively from everyday school life" (p. 225) resonates well with my research study. The teachers' initial thoughts, their actions and interactions in professional learning and classroom situations and their reflections will form the basis of discussions for understanding changes in their TPACK. This will directly provide answers to the research question in respect of knowledge and practice of the teachers involved.

This section has shown that there are ongoing debates and an ever-growing body of research around context in TPACK. Interpreting context based on the literature reviewed will be an intrinsic element in my work. However, understanding teachers' knowledge and practice in the context of this research study cannot be properly undertaken without an appreciation of the circumstances in which the teaching occurred, specifically the fact that planning and teaching occurred in teams. Hence, the next section provides a review of literature on team teaching focusing on how it is seen through the lens of TPACK.

Team teaching and TPACK

Anderson and Speck (1998) espoused the benefits of team teaching for learning as it "encourages multiple perspectives, promotes dialogue/increased participation, and improves evaluation/feedback" (p. 673). Although they were by no means the first researchers to examine team teaching, their work is significant for my research study, as it advocates for the involvement of students and teachers participating in learning situations, cooperating and learning together, seeing these as the very essence of constructivism (Anderson & Speck). The views of Anderson and Speck are further enhanced by more recent citations of their work by Vesikivi et al. (2019), who claimed teach teaching "encourages active participation" (p. 527). Such views align well with what has already been described as the focus of this research, namely the active involvement of students as SDLs working with teachers.

However, both Anderson and Speck (1998) and Vesikivi et al. (2019) were in higher education, with their research focus being on learning, not on teaching. They considered the effects on learning in university settings and how these experiences improved when students were active participants in the learning process. As my research focuses on secondary school teaching, citations of Anderson and Speck were explored to look for research in these areas. Through these searches, the work of Mackey et al. (2017) seems to have some highly relevant points, given they looked at team teaching in flexible spaces, which is the setting for my research. Mackey et al. completed a mixed method study of teacher experiences using team-teaching approaches in such settings. They saw benefits when "teachers work collectively and collaboratively within flexible learning environments to share their skills, strengths and expertise to improve learning outcomes for all" (p. 106). Such views align well with my research in that teachers of varying "skills, strengths and expertise" in using technology worked together. However, Mackey et al. did not consider including students working with teachers, nor was their research concerned with technology integration and, hence, there was no use of the TPACK lens.

At the time of writing, nobody appears to have cited Anderson and Speck (1998) when they have written about TPACK. I used both "TPACK" and "TPCK" as terms searching all the papers that have cited Anderson and Speck (1998), but no results were returned. Thus, I carried out a broader search for any research papers exploring team teaching and TPACK. The following paragraphs feature those papers which focus on any effects on teachers and teaching practice, where discussions and findings are considered relevant to my research.

Several studies involving TPACK and team teaching did not focus on classroom practice; instead, the emphasis was on designing courses in teams, for example, Koehler et al. (2004), Koehler et al. (2007) and Voogt et al. (2015). These are significant in that they draw attention to the "value of the collaborative process of course design" (Koehler et al., 2004, p. 17) where such collaboration enables teachers in design teams to "learn 'how to learn' about technology and 'how to think' about educational technology" (Koehler et al., 2007, p. 744) through

problem-solving and using technology together. Furthermore, such design team environments provide opportunities for teachers to learn more about TPACK itself (Voogt et al., 2015), although it should be noted that in all these research papers, the settings are in higher education. However, they are relevant to my research study as they have teachers planning and designing teaching in teams. This occurred in my research with the SDLs providing input at the design stage as well as in lessons. Hence, the question is whether the findings in literature regarding the benefits of collaborating with other teachers to design teaching and learning with technology is affected by the involvement of SDLs. This will be a focus on how the teachers' knowledge is affected.

A number of other papers focusing on TPACK and team teaching have looked at the concept of a mentor working with teams of pre-service teachers, for example, Bate (2013), Jang (2010), Jang and Chen (2010) and Habowski and Mouza (2014). These have highlighted how "pre-service teachers have learned to imitate and develop TPACK by observing mentor teachers" (Jang & Chen, 2010, p. 561) and how mentorship became "an integral part of the pre-service teachers' reported professional growth and development in all areas of TPACK" (Habowski & Mouza, 2014, p. 492). In other words, clear vindication for not only collaborative development of knowledge around teaching with technology but of those less experienced and, likely, less knowledgeable about integrating technology into their practice, to prosper from working with more experienced mentors. While my research does not have a system of mentors set up to work with pre-service teachers in the shape of more experienced teachers as featured in the research papers cited above, it does feature teachers with different experiences, confidence and skills in respect of teaching with technology and in teaching as a whole. These teach in various pairs, where one could be said to be more experienced than the other. Likewise, all the teachers in my research collaborate beyond the teacher they are paired with, as a teacher of PBL, with some pairs working closely with other teaching pairs on the course. Also, it could be argued that the SDLs may take on roles akin to mentors when they work with the teachers. Thus, it will be worth considering whether such relationships can be

viewed in a similar manner to how mentors and pre-service teachers' collaborations have enabled the development of TPACK and what influence SDLs have had in that.

Specific papers where the knowledge and practice of teachers are examined using a team-teaching approach through a TPACK lens are few and far between. However, in M. D. Phillips (2014), the focus was on how TPACK is developed and enacted in a workplace setting, namely a secondary school with teachers working together in teams. The findings clearly supported the concept of TPACK being shared practice and shared knowledge rather than individual. Hence, there was support for the existence of distributed knowledge argued by Nore et al. (2010) and Di Blas, Paolini, et al. (2014) (Section 2.1. – Knowledge development in TPACK). The work of M. D. Phillips (2014) goes far more in depth than an examination of knowledge and how that is represented through practice by teachers. It is concerned with "the ways in which a professional's identity within a CoP shapes the enactment of their TPACK" (M. Phillips, 2017, p. 1794). As such it requires understanding of CoP and associated literature. Thus, the work of M. Phillips will feature heavily in discussions on team teaching and CoP in Section 2.3. (CoPs, technology integration and team teaching).

The literature reviewed in this section has provided existing research and viewpoints relevant to team teaching, in particular where it has been viewed through the lens of TPACK. It shows a number of theories regarding knowledge and practice of teachers that could be evidenced through analysis of the data in the case studies later in this thesis, which helps to answer the research question. However, none of the literature on team teaching, to date, discusses students as part of the teaching team or considers the effects on teachers in teams when students are actively involved in influencing their knowledge and practice in respect of technology. There have been no studies where students have been put into roles with teaching teams, and the effects of this have been examined. However, literature exists looking at various forms of having students actively involved in the teaching process, and this will be examined in the next section.

2.2. The active involvement of students in technology integration

KeenGwe et al. (2009) described several "great opportunities to enhance classroom instruction" (p. 17) that technology can provide to teachers. They included potential for greater authenticity in discipline integration, improvements in approaches to demands for personalised learning and the ability for teachers to provide students with far greater control over their own learning. The provision for greater student-centred approaches to learning are far from a modern phenomenon nor do they necessarily arise out of developments in technology. They have very strong links to the much-lauded research of Vygotsky (1978a), Piaget (1964) and Dewey (2004), which paved the way for changes in beliefs about how humans learn. The principles of constructivism at the heart of student-centred teaching and learning are not without their critics, though. Kirschner et al. (2006) found that there was no empirical evidence to support the use of constructivist approaches to teaching and learning, giving full backing to the role of a teacher as provider of direct instruction. A more balanced view calling for more in-depth research into the impact of constructivist approaches was offered by Mayer (2004).

For the purposes of this research, constructivism, in itself, is too broad a term to provide explanation for the active involvement of students in education. There is a need to explore specific pedagogical approaches that sit within constructivist ideals and provide opportunities for increasing the active involvement of students in the technology integration process. In respect of this research, I intended to further extend the belief that digital technology advancements lead to "a need to expand our vision of pedagogy so that learners are active participants or co-producers" (McLoughlin & Lee, 2007, p. 664). Concepts of students actively involved in the teaching process and student-led activities is not a new thing, though, and research from this section will give an insight into relevant issues when this has been done.

Students involved in educational technology

Studies have been undertaken involving students in educational technology in schools (Corso & Devine, 2013; Martinez, 2007; Martinez, 2008; Passey, 2013, 2014; Peterson, 2012). All of them have indicated various positives of such involvement for both the students and the education community in which they work. These papers are detailed below with explanations as to how they link to this research.

Passey (2013) provided a meta-analysis on the impacts of technology integration on learning. He talked about how technology can be used to support different groups of learners and the positive impact learners can have in supporting other learners through sharing their knowledge and skills with technology. In 2014, he directly looked at students in similar roles to what is intended in this research. He provided case study evidence of student SDL schemes being deployed in schools. However, the focus in Passey's (2014) work was on intergenerational learning, on the SDLs themselves. He found that the scheme "enables students to contribute positively to the community, rather than just receiving from it; students become school community contributors as well as receivers" (p. 15). His research did not expand to teachers in that community, and his calls for further research support the focus areas of this research study.

Passey (2014) provided a case study looking at the implementation of student SDLs through the lens of intergenerational learning practices, which highlighted positive effects on students in terms of leadership and skills development and on teachers in improving their digital skills when they were involved in technology implementation in education settings. However, as argued in the literature review of Waite (2017), there is a need for further research in this area as Passey did not "quantitatively evaluate the impact on teaching and learning nor define the pedagogical approaches used" (p. 39). My study intended to provide further research in respect of looking at the SDLs' influence on teachers and practice through the lens of TPACK, exploring both the impact on teaching and the pedagogy used.

Corso and Devine (2013) espoused similar positive effects on students when involved in roles akin to SDLs but their research went further into describing the positive effects on teachers through having students as mentors. The idea of students as mentors is central to the research of Martinez (2007) and Martinez (2008), which links to the well-established GenYes program described by Chuang (2006). The GenYes (n.d.) services are bought-in consultancy-based programs where schools are assisted in involving their students in technology integration. Chuang described the GenYes program, where students provided mentoring for teachers as having success in supporting teachers to plan and develop their teaching resources to integrate more and better use of technology. The work of Peterson (2012) extended the concept of students as mentors labelling this as reverse mentoring. However, in all of this work, despite detailing influences that SDLs have had on teaching practice, there has not been a focus on how this happens.

In summary, it is clear that research exists where students have been involved in professional development activities intended to contribute to integrating educational technology in school settings. In all of these, however, there has been a call for further research. This research study intended to focus on teachers. It analysed how the introduction of teachers working with SDLs influenced the teachers' knowledge and practice. It was not confined to mentorship nor was it concerned with either the effects on students or the wider school community. Specifically looking at students in active roles and how they have affected teaching practice has happened in other areas unrelated to technology integration; this is described in the next section.

Examples of students in active roles

Having students as researchers is an approach for enabling the active role of students in the teaching process. Steinberg et al. (1998) described teaching practice involving students in active roles as researchers. Their research was intended to challenge the concept of teaching theory or application of theory to students, within given rules set by previous research and

well-known practices. Having students immersed in such roles was intended to provide student-led perspectives, education and research data that can affect teaching and learning in the subjects being taught (Elmesky & Tobin, 2005).

However, despite Elmesky and Tobin (2005) seeing the potential for students as researchers to affect teaching and learning, the basis and reasoning behind the use of students as researchers lay not in changing the practice of teachers, rather, it was in changes in the practice, thinking and development of learners. In contrast, this research has wanting to change how teachers teach, how technology is perceived, how its use is permitted and the reality of use in classroom practice as its fundamental driver. Further, this study is reliant on certain perceived skills in and experience with that some students have with technology as well as their exposure and immersion in a digital culture, which leads them to practices (social, community-based, communicative, collaborative) being utilised and developed to influence technology integration in education and change classroom practice.

One of the major drivers in having students as researchers was an attempt to address inequity in student access to learning (Atweh & Burton, 1995; Elmesky & Tobin, 2005). Similar sociocultural and political foundations for research can be seen in many examples of critical pedagogy where "students act on and use their generated knowledge for self- and social transformation" (Wink, 2011, p. 29). As with methodologies for having students as researchers, critical pedagogy has, at its core, the principle of empowering students in order to work for change (Cobiac, 1994).

Where critical pedagogy is used, the teacher attempts to remove the hierarchical position they hold in teaching a class, promoting students as co-learners (Shor, 2012). Since its introduction by Freire (1968/1970), the methodology has been viewed as being too abstract and without the necessary connections with vital pedagogical elements such as curriculum and assessment (Stern, 2011). However, given it was motivated by Freire's desire for students to develop critical consciousness and to challenge the structures, systems and authority in

education, it is perhaps inevitable that such connections will be absent.

In terms of the active role of students, it is important to recognise Giroux's (1997) views: "classroom pedagogy in varying degrees is inextricably related to a number of social and political factors which includes…the way students perceive their classroom experiences and how they act on those perceptions" (p. 16). A key factor in Giroux's interpretation and application of critical pedagogy is having the students act on the basis of their views towards the teaching and learning they have experienced. This may suggest facilitating students to have a voice in their education, but "a critical pedagogue teacher must attempt to hear that student voice." (Kanpol, 1999, p. 50).

Critical pedagogy offers education the notion of power and change (Johnston, 1999). There are contentions over whether students are actually given power to make choices or are in fact being manipulated by educators' ideals (Ellsworth, 1997). Thus, in this research, the focus was on students taking active roles in technology integration whether they are given all the power to do so or not. Students having active roles will involve giving students some power, but some decision-making may be out of their control.

Giving students power and opportunities is also a key feature of democratic schools, where a large portion of the decision-making seems to be shifted from the hands of the teachers to the students (Wilson, 2015). Such schools offer students freedom to "organize their daily activities, and in which there is equality and democratic decision-making among young people and adults" (Miller, 2007, p. 36). This is also known as democratic education, where students are provided with opportunities to play key roles in their own education and that of the school (Wilson, 2015). Korkmaz and Erden (2014) recognised complexities in defining democratic schools and their attempts at identifying characteristics produced a lengthy list. However, the "participative decision-making mechanisms" (Korkmaz & Erden, 2014, p. 371) is a distinguishing feature when compared to more conventional schools.

The concept of democratic schools appears to follow closely the principles of critical

pedagogy although there are fundamental differences with critical pedagogy's focus on social justice and democratic schools being centred on the equal participation of students and teachers (Edwards, 2010). As with critical pedagogy, democratic schools provide students with a voice (Wallin, 2003). In this respect, students' perspectives, viewpoints and opinions on education are not only heard but also provide opportunities for reform (Cook-Sather, 2006). Several commentators claim that there is potential for contemporary student voice activities to lead to radical transformation of educational practices (Fielding, 2001, 2004; Mitra & Gross, 2009). However, there is a risk of tokenism in respect of giving students a voice (Macbeath & Mortimore, 2001). Rudduck and Fielding (2006) highlighted a need for the schools to consider the logistics around having student voice and how these can affect decisions in a school.

Fielding (2004) said that student voice activities have the capacity to prompt the "intermingling and interdependence of both" teacher and student roles in education (p. 296). Echoing the sentiments of Kanpol (1990), Fielding (2001) called for recognising the transformative impact of providing students with a voice but also ensuring student voices are not only listened to but acted upon, provision of which requires organisational and systems considerations in schools. Fletcher (2010) argued that ensuring the voice of the students has some impact, which relies on ensuring they have active roles in their learning and in the decision-making of the school. It could be argued that active roles in their learning and decision making described by Fletcher (2010), could be more defined, though, and this research study intended to address this issue in some respects.

This research intended to give students a voice very much aligned to Cook-Sather (2006) in providing opportunities for reform. It should be noted, however, that there are clear differences between the underlying motives not only for some examples of student voice but also for democratic schools and critical pedagogy, when considered against the motives of this research. Reform as described by Cook-Sather suggested focusing on education reform. While whole-school integration of technology were analysed, such large-scale plans were not

intended here. In respect of democratic schools, their motives are improving social equality. Apple and Beane (2007) depicted schools and the educators changing to a democratic way of working as having a desire to uphold and even promote democracy – but not just democracy in the school itself, more as an agent for greater democracy in the wider community. Similarly, critical pedagogy, particularly in Freire (1968/1970), has political motives beyond the classroom or indeed the school where it is in use. Despite these differences, they offer great insight into issues of power and how it changes when students are in active roles. These issues are significant considerations not just in establishing ways of actively involving students in the technology integration process in schools but also in the way they affect teachers and relationships between students and teachers when schools actively involve students in technology integration processes.

This study involved students in a collaborative learning process with teachers. How students influenced teachers' knowledge and practice and an insight into the interactions as well as the relationships between students and teachers working together will provide better understanding of any developments. Given the demand for analysis of interactions and relationships and examining learning as a social experience, an appropriate theoretical lens was required. CoPs offer such a lens.

2.3. CoPs

Previous discussions in this thesis have examined literature on frameworks and models to scrutinise issues of technology integration in education and related examples of empowering students in the teaching and learning process. A central focus in this research is the concept of students being actively involved in affecting how teachers acquire the knowledge to use technology in their teaching practice, in other words, in how they learn in relation to education technology. Examples of research have been featured with students actively involved in the teaching process and student-led activities. However, reviewing this literature has highlighted that there seems to be little in the way of examples to support the belief that

advancing teachers in their capacity to use digital technology in their practice should involve having students as "active participants or co-producers" (McLoughlin & Lee, 2007, p. 664). This study aimed to redress this shortcoming by investigating students involved in "active participation" and "co-production", working with teachers on various projects that provide opportunities to analyse what effects actively involving students in the technology integration process, has on teaching practice.

In order to answer the research question *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?*, there was a need to analyse more than the simple transmission of information between the parties involved. Given the lack of research on having students training teachers and co-producing curriculum content, I anticipated that these would be relatively unique learning situations where "social relations and meanings that grow up around a work process" (A. Cox, 2005, p. 537) will occur. These relations and meanings of the students and teachers involved are the focal points for analysis. A CoP, in particular Wenger's 1998 publication *Communities of Practice: Learning, Meaning and Identity*, offers an appropriate lens for such an analysis, as this chapter will explain. An examination of the theories underpinning CoPs is an ideal starting position before unpacking Wenger's (1998) work.

Defining a CoP

Although common practice in society, a CoP differ from communities that share an interest, as there is an implication that those involved share practice and share a sense of belonging (Wenger, 1998). Further, according to Wenger, each CoP is relatively unique, but all have defining characteristics, namely what the agreed purpose is for the CoP coming together, the way it operates and the resources the members of the CoP have developed for themselves. Having projects where students and teachers learn and develop together should see many of these CoP characteristics.

The community element of a CoP in this research requires clarification as it includes both

teachers and students. There is the "need to extend associational life within schools" (Wenger, 2009, p. 6), and my epistemological belief is that this will be an essential component of having students active in technology integration as described. There is also an argument that the term *community* implies "harmony and togetherness" (Hughes et al., 2006, p. 20) of those participating. In other words, there is a suggestion that all teachers and students in schools where this research is carried out will fully embrace it and want to be involved. This is far from the truth as it is expected that members of both the teacher and student bodies will have those reluctant to be part of some or all of the CoP. Thus, there was scope in this research for closely examining "the gloss of community" (Fuller, 2007, p. 18), commenting on how the teachers involved in a CoP interact when there is reluctance or unclear relationships for instance.

This research looked to shift the focus of the relationships and interactions to those that occur between students and teachers when their roles are challenged; at times, the teachers became learners with students teaching. Rogoff et al. (1996) espoused the benefits of adults and children together and from each other. Participating in a shared learning community as Rogoff et al. described, implies the issues of switching roles between students and teachers as well as the ideology of participants in a school community learning together.

Head and Dakers (2005) delved further into the implications for education, describing the outcomes of implementing a CoP in education as a change in pedagogical practices. As teaching and learning activities are planned together, there is greater collegiality between students and teachers (Head & Dakers, 2005). However, the essence of their research was in students and teachers designing tasks together and the students becoming peer-educators for others in the classes. There was a suggestion of teachers being learners but nothing more. This research provides for analysis of situations where learning is by student and/or teacher, as described by Rogoff et al. (1996), and also when teaching can also be the role of the student or the teacher depending on the subject in question.

Understanding that a school is a site of learning and the relations and meanings between students and teachers is essential to understanding the development of CoP (Wenger, 1998). Sustaining participation is essential for professional development to be effective and that comes from community cohesion (Henderson, 2007). The CoP lens provides a way of critically examining the active involvement of students in the technology integration process as part of the school community, leading to a better understanding of any changes in teachers' knowledge and practice and how these occur.

According to Fuller (2007), in a CoP, Wenger saw "the collective or group as the important unit of analysis rather than the individual. Individuals are important in so far as they learn by being in social relation to others" (Fuller, 2007, p. 19). Seeing learning as a social process (Wenger, 1998) positions a CoP as a lens for understanding teachers' learning when they share practice within the projects proposed in this research. Fuller summarised the CoP learning concept as one which promotes the group as an important unit rather than the individual, where learning takes place within the shared practices of the community, where learning is a social process and not a final product, where members contribute to the learning as they participate in the shared practices of their community regardless of their novice or expert status.

According to Wenger (1998), from a CoP perspective, members of the community not only learn from one another as they negotiate the meanings of their practices but also create new knowledge and improve the existing practices of their community. Such fluidity to the notion of learning suggests a broader analysis than formal professional learning provision such as training programs. Wenger (1998) argued that learning is a continuous process that occurs in our every-day practice. Thus, for this research, it was important that the concept of the professional learning of teachers was seen as not only what happened in planned activities or programs but in many other situations within their practice.

Fuller's (2007) critique of CoP theories supported Wenger's broad view of social learning,

highlighting certain misconceptions. For this research project, the most notable of these misconceptions is that learning is a knowledge transfer from an expert (teacher) to a student. This research intends to try to understand effects on teaching practice from increasing the active involvement of students in the technology integration process, positioning students as the perceived experts in relation to technology. Fuller (2007) and Hughes (2008) also pointed to a misleading assumption that learning occurs only in formal settings, however. Such a view aligns CoPs with sociocultural learning ideas, suggesting that CoPs are grounded in theories of situated learning.

Theoretical basis of CoPs

Situated learning was described by Vygotsky (1978b) as creating meaning from day-to-day activities, where learning takes place through the relationships between people, their connections with prior knowledge and the context in which the learning occurs. Lave and Wenger (1991) termed situations where such learning occurs in CoP as *legitimate peripheral participation*. A succinct explanation of legitimate peripheral participation is "engagement in social practice that entails learning as an integral constituent" (p. 35). This stems from the belief that learning should be viewed holistically, situated in a social and cultural environment, with learners participating in common practices (Lave & Wenger, 1991).

Underpinning CoP theory is seeing "learning as social participation" (Wenger, 1998, p. 4), where learners are involved in a "process of being active participants in the *practices* of social communities and constructing *identities* in relation to these communities" (p. 4). As such, learning involves reshaping the identities of those participating in communities sharing practice. In other words, it is a social theory of learning that incorporates community, practice, identity and meaning for those who participate. Learning is not seen as an isolated or an individual process, as removing the issue of the learner's context would be to look at the concept of learning as being abstract when the reality is directly the opposite (Brown, 1993). Hence, analysis of learning from this perspective is the same as analysis of the elements of a

CoP.

Lave and Wenger (1991) described a process where newcomers to a CoP become more established members as legitimate peripheral participation. The concept is that there is a structure, an environment where those that come to the CoP with little or less experience than others more established within the CoP will learn through their interactions with the more established members of the CoP and involvement in the CoP itself. Newcomers to a CoP develop from a peripheral position within a CoP to full participation. The process by which newcomers develop recognition as members of a CoP follows processes that those who are established in CoPs have previously experienced – "the process of learning is not essentially different" (Wenger, 1998, p. 102). Hence, there is the implication that learning is an ongoing and developmental process in which participation and a participant's identity change as their role within the CoP changes.

The belief that "learning involves the construction of identities" (Lave & Wenger, 1991, p. 53) was highly significant in the theory of legitimate peripheral participation, yet Wenger (1998) saw a need to champion identity and CoP using these "as the main entry points into a social theory of learning" (p. 12). Lave and Wenger espoused a dual relation between practice and identity in a CoP. Furthering this, Wenger (1998) used practice and identity as the cornerstones of his theory of social learning. As this research intended to use CoPs as described by Wenger (1998) to conceive of how teachers' practice and identity evolve and change during the study, an in-depth understanding of these areas is essential.

Understanding the concept of practice

According to Brown and Duguid (2001, p. 203), "by practice we mean, as most theorists of practice mean, undertaking or engaging fully in a task, job or profession". Although this concurs with Wenger (1998) in that it positions practice as a social entity, it omits to include the essence of learning. One could argue that Brown and Duguid's distillation of the term *practice* could be achieved without learning. Conversely and perhaps more simplistic is the

view that those who share practice are involved in "collective learning" (Wenger, 1998, p. 45). This sense of the communal aspect of learning is at the heart of the definition of a CoP.

Practice is far from simplistic, however, when it is considered as "doing in a historical and social context that gives structure and meaning" (Wenger, 1998, p. 47). Additionally, as it "includes both the explicit and the tacit" (p. 47), there is the essence that practice is deeply interwoven within the fabric of a CoP and the participants therein. Historical approaches, traditions, conventions, assumptions, understandings and relationships between the participants of a CoP contribute to defining and shaping practice in a CoP. As the relationships and roles within a CoP change, this will affect practice. Hence, there is the notion that practice has fluidity; it is developing within a CoP.

With the understanding that practice has fluidity and is heavily influenced by the multifaceted elements of a CoP, Wenger (1998) referred to how participants in a CoP interpret and formulate views and understandings as negotiation of meaning. He then further refined negotiation of meaning, elucidating that "participation and reification refer to a duality fundamental to the negotiation of meaning" (p. 55). Participation is in the sense of active participation by the individuals involved in a CoP. Their history, practices and involvement in the CoP contribute to how they negotiate meaning. Reification, on the other hand, refers to the interpretation and realities participants of CoPs construct from trying to make meaning.

According to Wenger (1998), processes of reification and participation are often inseparable. However, their role in the negotiation of meaning offers an insight into how what those involved in a CoP do; what they say, what they interpret and how they communicate their interpretations, all play a significant role in trying to understand practice. Thus, in this research study, analysis of the teachers in terms of how they behaved as they did, the roles that they took in the various ways of working together, viewed through the lens of CoP, will be a conduit to recognising any changes to teachers' practice when working with students in

their active roles. Conceiving, as Wenger portrays, that practice is in-depth and worthy of close examination potentially creates multiple leads that can be followed to answer the research question.

According to Wenger (1998), “practice is the source of coherence of a community” (p. 72), and by practice and community being associated, a CoP can be defined. Practice can be broken down into three dimensions: mutual engagement, joint enterprise and shared repertoire. As Henderson (2007) points out, these dimensions are at the heart of the cohesion of a CoP. He highlights how “in order to move from legitimate peripheral to centripetal participation, community members need to increasingly invest in the mutuality of engagement, the joining of enterprise, and sharing of repertoire” (p. 49). The level of participation and whether SDLs are part of teacher CoPs will be significant in this research study. Hence, it is important that characteristics of the three dimensions are outlined so that they can be recognised from data collected. These are provided in Table 2 below reproduced from Henderson (2007, pp. 50–51) using Wenger (1998) as a source:

Table 2: *Defining the elements of cohesion (Henderson, 2007, pp. 50–51)*

Elements of Cohesion	**Characteristics**
Mutual Engagement is	• Doing things together • Sharing in an activity (MacBeath, 2003) • Being included in what matters • Relationships between members: members form mutual relations of engagement • Membership: it defines membership, that is the practices of a community and the context for belonging • Community maintenance: the formal and informal work that enables engagement • Negotiating Diversity: members are not homogenous, they find a unique place and identity within the community. Mutual engagement is as likely to facilitate differentiation as homogenisation. • Understanding Partiality: individuals cannot define or encapsulate the entirety of the Community of Practice. Mutual engagement is understanding members' competencies, that is, what each member can and cannot do and being able to tap into those skills and knowledge. • Making sense of the world: people are engaged in actions whose meanings they negotiate with one another
Joint Enterprise is	• Responding together • Mutual accountability. This is a socially negotiated understanding of what matters, what is important, what needs to be done and what can be taken for granted. It includes knowing what can be ignored, what should not be done, and what should be left unsaid. It is having a sense of what needs to be justified, what is good enough and what needs improvement. • Locally responding to global needs and institutional pressures • Reconciling competing demands (MacBeath, 2003). • Understanding and judging quality (MacBeath, 2003) • A negotiated response to their situation (and thus belongs to them in a profound way, which also makes it difficult for non-members to observe and articulate) • Not immune to the "pervasive influence of the institution" (Wenger, 1998b, p. 79). A CoP can be influenced, manipulated, duped and intimidated, but it can also be inspired, helped, supported, enlightened and empowered. • Not necessarily a harmonious or identical response, but rather a response which has been shaped, and given meaning through mutual engagement. • A local means to satisfying or avoiding institutional demands. "Even if strict submission is the response its form and its interpretation in practice is a local collective creation" (Wenger, 1998b, p. 80). • Both a source and direction for social energy. "It spurs action as much as it gives it focus" (Wenger, 1998b, p. 82).
Shared Repertoire is	• Resolving problems together • Using and creating communal resources in the process of negotiating meaning • A socially negotiated, and therefore profoundly unique, understanding of routines, words, tools, ways of doing things, stories, gestures, symbols, and actions of community • A historical reflection of mutual engagement • Boundary formation (Thorpe, 2003). People who cannot understand the reified objects of a community, and who do not share the community's discourse cannot fully participate in that community.

However, it is also worth noting that any study of CoPs cannot occur in isolation. As Wenger (1998) described, the members of a CoP have “histories of articulation with the rest of the world” (p. 103); thus, any analysis of participation in a CoP has to consider that those being studied have previously been members of other CoPs and are currently members of other CoPs. This concept of multi-membership sees participation and reification play an important role connecting CoPs where Wenger outlined the roles that boundary objects and brokers play in this. Participation and reification refer to the connections between communities and the elements of practice that can be provided through those connections across communities. Participation, reification and brokering are factors that may be highly relevant in my research, as students come into teachers’ CoPs to provide professional learning but do not become members of those CoPs. The SDLs may move between CoPs and influence events and members in those CoPs. Further, materials which serve as boundary objects may be created.

Boundaries are created around CoPs in various ways, such as the “nuances and jargon of a professional group” (Wenger, 1998, p. 104), how one gains access to the CoP, maintains memberships and identifies as part of the CoP. They are also created from titles given to those who are members of a CoP. However, Wenger went on to explain that these boundaries not only serve to form a barrier to entry and to participation but they can also be said to create connections. Participation in a CoP and the reification that occurs as practice within a CoP contribute to the existence of boundaries which those who are outside the CoP would face as a barrier to entry. In contrast, the example Wenger (1998) used of how claims processors “are not connected in very direct ways to the content of the claims they process, yet are still able to do their work” (pp. 106–107) highlights how certain boundary objects can connect CoPs.

As reification occurs as part of the development of practice within a CoP, the "products of reification can cross boundaries and enter different practices" (Wenger, 1998, p. 105). These products can be both physical and conceptual. For example, they could be the language or terminology used, ideas, procedures or concepts as well as the physical materials that a CoP

uses, such as paperwork or, more relevant to this research study, training materials. When they are designed within one CoP or by an individual, with certain intentions and then used in a different CoP, they influence the CoP in which they are used. As Wenger portrayed it, this is a dual role that these boundary objects play.

This research study saw students creating learning materials with specific intentions for use by multiple teachers who may have interpreted them differently. Likewise, they worked with, communicated and trained multiple teachers, and during these interactions, the teachers may have been introduced to new concepts. Any of these could influence not only the individual teacher's knowledge but also, depending on how they share within a CoP, the practice of the community. Looking at boundary objects as artefacts with a "nexus of perspectives" (Wenger, 1998, p. 108) provides the potential to make meaning when they are used, therefore influencing practice in the CoP.

There is another way that connections can be made to and from CoPs, which does not come through reification. Instead, it can come from brokering, according to Wenger (1998). Brokering is when one person from a CoP enters another CoP and the practices they have developed or learned are introduced, akin to a cross-pollination of practices. Being an effective broker is difficult, however, as it "requires an ability to manage carefully the coexistence of membership and non-membership, yielding enough distance to bring a different perspective, but also enough legitimacy to be listened to" (Wenger, 1998, p. 110). In other words, there can be pressure to become part of the CoP, but credibility as a participant is difficult when one assists only in the enterprise of the CoP rather than becoming a fully-fledged member.

To relate the concept of brokering to my research, there may be practice that teachers exhibit through previous involvement as members in other CoPs. This may have influenced members of the community analysed in this research study. However, it may also be possible to identify multiple CoPs operating in the school in question, where teachers "transfer some

element of one practice into another" (Wenger, 1998, p. 109) or where the students are seen as brokers as they work with different teachers and move between teachers' CoPs. The legitimate peripheral participation of the students involved will likely see them participating in a limited or partial role rather than being centripetal to the CoPs they work with. Practice they share across the boundaries of CoPs they work in may relate to the artefacts that they create, but it may also relate to what they experience or learn in one CoP and then share with another.

The issue of being a credible participant in brokering is something that could be a significant factor for this research study. There are fundamental questions as to whether teachers will be influenced by students, will change their practice as a result of interactions with students teaching them or, as previously cited, will students have "enough legitimacy to be listened to" (Wenger, 1998, p. 110). Following Wenger's concept of legitimate peripheral participation, whether the student's interpretation of a teacher's practice is seen as legitimate or the advice in general is accepted will be key to whether the influence of teacher knowledge and practice occurs.

Explorations of practice cannot be carried out without considerations of identity, though. The relationship of practice and identity is so strong that looking at identity is described as "a shift in focus within the same general topic" (Wenger, 1998, p. 145). Moreover, Wenger saw a focus on identity as a chance to explore "non-participation as well as participation, and of exclusion as well as inclusion" (p. 145) in a CoP. These are factors which could be significant in this research study. Hence, the natural progression is to review the literature on the issue of identity in a CoP.

Understanding the concept of identity

In the context of a CoP, identity is constructed through "negotiating the meanings of our experience of membership" (Wenger, 1998, p. 145). To analyse this further, it is through an individual's approach and interpretation, understandings and misunderstandings, prior

knowledge and experience or lack thereof, while participating in a CoP, that identity is formed. There is, thus, a strong sense of connection between practice and identity, as can be seen in Figure 3 below:

practice as…	identity as…
• *negotiation of meaning (in terms of participation and reification)*	• *negotiated experience of self (in terms of participation and reification)*

Figure 3: Parallels between practice and identity (adaption) (Wenger, 1998, p. 150)

Adapted from a more comprehensive summary of parallels offered by Wenger, practice and identity are both seen to stem from participation and reification. Wenger (1998) referred to identity as a "layering of events of participation and reification" (p. 151), where events in a CoP over time, who participants interact with, what interpretations are made and concepts made into reality, determine identity in the practices of CoPs.

Seeing the formation of identity through events, Wenger (1998) referred to it as a continual developmental process as people participate in various CoPs throughout their lives. As such, this process provides for different avenues through which individuals understand their own identity. However, for this research study, it was also important that participation in various CoPs needed also to be considered within the school. As Wenger (1998) stated, CoP exist "inside and across organizations, schools and families – in both realized and unrealized forms" (p. 228). Thus, the whole school can be seen as a CoP, but within that CoP there are often numerous other CoPs, for example, for each faculty, across the teaching of particular year group or, highly relevant to discussions in this thesis, in team-teaching structures.

In a paradigmatic sense of how Wenger (1998) viewed formation of identity, "newcomers must find their own unique identities. And the relation goes both ways; newcomers also provide new models for different ways of participating" (p. 156). Consequently, in relation to this research study, there may be teachers who can be viewed as newcomers and as such they will be forming individual, unique identities, as Wenger described, but these teachers may

also provide "new models" for participation. Through their formation of identity, the way that newcomers respond to working with SDLs may be affected, and as such becomes an interesting discussion point in my work. Given this, the next section focuses on the significance of how identities are formed in CoPs through trajectories.

Trajectories

Wenger (1998) explained identity formation as an ongoing process for members of a CoP. He says that identity is not "something we acquire" (p. 154); rather, it is "a constant becoming … always going on" (p. 154). Recognising that identities are formed continually as participation occurs in various CoPs and identities are shaped by participating in each CoP we become a member of, Wenger labelled this as "the concept of trajectory" (p. 154). Through the continual ways members of CoPs form their identities, trajectories have "a coherence through time that connects the past, the present and the future" (p. 154). With this in mind, data was analysed to look at how teachers' trajectories, how they "incorporate the past and the future in the very process of negotiating the present" (p. 154) affected any influence SDLs had on their knowledge and practice.

Wenger (1998) named five types of trajectories: peripheral, inbound, insider, boundary and outbound. The first four of these could be significant in some ways, depending on the teachers in this research study and where they saw themselves in the CoPs involved. To expand on these: there may be teachers whose trajectories "never lead to full participation" (p. 154) as they remain peripheral; newcomers who are on inbound trajectories; and members of CoPs who are considered to have full membership, which suggests they have insider trajectories and trajectories that "find their value in spanning boundaries and linking communities of practice" (Wenger, 1998, p. 154), which will be discussed in terms of brokering where it is significant in the case studies. Outbound trajectories are largely outside the scope of this research as they "lead out of a community" (p. 155) and are concerned with "what comes next" (p. 155), which does not really relate to answering the research question.

Viewing members of a CoP as being on a certain trajectory may also be helpful in this research study, in the consideration of identities of non-participation. Recognising that individuals experience a mixture of participation and non-participation that contribute to "processes of community formation" (p. 168) may explain the actions and behaviours of different teachers with regard to their involvement with SDLs. This may, in turn, affect the level of influence the SDLs had on their knowledge and practice. Hence, the next section will focus on participation and non-participation.

Participation and non-participation

The way identity forms in a CoP does not relate solely to what individuals participate in:

> We not only produce our identities through the practices we engage in, but we also define ourselves through practices we do not engage in. Our identities are constituted not only by what we are but also by what we are not. To the extent that we can come in contact with other ways of being, what we are not can even become a large part of how we define ourselves. (Wenger, 1998, p. 164)

This statement refers to what Wenger described as the identity of non-participation, where he highlights that although identity develops through participating in communities, interactions of non-participation can also be significant. Wenger argued that non-participation is inevitable as "our own practices usually include elements from other practices, and … we inevitably come in contact with communities of practice to which we do not belong" (p. 165). However, Wenger acknowledged that not all events become significant although they "can all contribute in their own ways to our experience of identity" (p. 165). Hence, there may be evidence in the data collected in this research study that can be interpreted as non-participation but the degree to which this is significant needs to be considered when looking at the teachers' identities in respect of any influence SDLs might have on them.

When considering an identity of non-participation, Wenger (1998) provided an example and explained this in relation to trajectories: "for a novice not to understand a conversation between old-timers becomes significant because this experience of non-participation is

aligned with a trajectory of participation" (p. 165). This highlights that he considered that certain trajectories that individuals are on, may "determine the significance of forms of participation" (p. 165).

Wenger (1998) pointed out two particular "cases of the interaction of participation and non-participation" (p. 165) – peripherality and marginality – which he described as providing different experiences as they involve different blends of participation and non-participation, hence they affect an individual's identity differently. Peripherality refers to where "some degree of non-participation is necessary to enable a kind of participation that is less than full" (p. 165). Newcomers would likely be on a peripheral trajectory where "non-participation is … an opportunity for learning" (p. 166). On the other hand, marginality is "a form of participation that prevents full participation" (p. 166), and Wenger highlighted that marginality usually affects more "long-standing members" (p. 166). With all this in mind, any pointers to where teachers are experiencing non-participation should be discussed with consideration of the evidence of the trajectories that the teachers are on. This may provide different perspectives on the interactions they have and the practice they display in relation to the introduction of SDLs.

Moreover, it is of particular significance "when participation and non-participation interact to define each other" (Wenger, 1998, p. 165). From the perspective of legitimate peripheral practice explained earlier, peripherality and marginality are two types of interactions in this respect. In both of these interaction types, there is potential to look at non-participation and participation as factors that affect the way those involved relate to each other and events in a CoP. Wenger highlighted the idea that trajectories are important in looking at engagement as a mechanism of belonging to a CoP. The paths that members of CoPs are on may determine their engagement and hence where they position themselves in a CoP.

As there were teachers with different trajectories involved in this research study, both peripherality and marginality could be relevant. Peripherality and marginality could be factors

as there may be teachers who do not seem to fully participate in CoPs being observed. According to Wenger (1998), full participation is an essential component of learning and of participation, in other words, of mutual engagement. Questions arise, however, as to understanding what constitutes mutual engagement or what the focus was for mutual engagement in the context of the school in the study, the teachers involved and the SDL strategies they were exposed to. It could be that there was mutual engagement around enhancing student involvement and the enhancement of student learning outcomes. However, there may be other forms of mutual engagement seen through analysis of the data. Wenger (1998) said, "being included in what matters is a requirement for being engaged in a community's practice" (p. 74). Hence, the foundations for analysis in levels of engagement, participation and the trajectories of the teachers involved relies on identifying factors that actually matter to the CoPs being studied.

If there were some teachers forming identities influenced by non-participation in my research, this requires a consideration of "modes of belonging other than engagement in practice" (Wenger, 1998, p. 173). Modes of belonging are about making sense of processes of identity formation and learning where there is a consideration of not just engagement but also of imagination and of alignment. According to Wenger, this prompts consideration of factors outside the CoP, "broader businesses processes" and "social processes" (p. 173) that influence identity but are outside of a CoP's daily practice.

Engagement, a mode of belonging, was described by Wenger (1998) as "the conjunction of: 1) the ongoing negotiation of meaning 2) the formation of trajectories 3) the unfolding of histories of practice" (p. 174). It is in the marriage of these three processes where practice and identity come together, that an individual's engagement can be seen. When looking at modes of belonging, engagement is said to have a "bounded character" (p. 175). This refers to limitations in terms of how much time those involved in a CoP can be engaged in practices, and the reality of being involved in more than one CoP brings restrictions to the amount of time one is present. Teachers will undoubtedly be involved in many different CoPs within and

outside the school; therefore, in my research, this could be pertinent to understanding engagement. However, it is important to note that Wenger saw bounded character as "both the strength and the weakness of engagement as a mode of belonging" (p. 175). The notion of engagement having a bounded character means it can afford or constrain the power of a CoP member when negotiating enterprise. Such power shapes the context in which one can construct and experience an identity of competence (Wenger, 1998). Engagement is not the only consideration in formation of identity, though. Imagination and alignment also need to be discussed.

Imagination, argued Wenger (1998), is the idea that there can be two members of a CoP doing the same thing but their perception of what it is they are doing is different. Additionally, the concept of imagination can be used to explain the way members of a CoP perceive other members doing different jobs or the same job but in different areas of the same organisation (Wenger, 1998). To relate this to a school environment, observations could be made of how teachers made assumptions, for example, how they perceived their role, the role of their peers and the SDLs involved in the research. Similarly, there may be evidence of differences between how some teachers viewed the learning provided by the SDLs and how other teachers viewed the same thing. Also, imagination may be an important factor in determining a teacher's mode of belonging in terms of perceived trajectory and the effect this has on engagement. Imagination, in this sense, may be a positive factor but it can also be a negative factor through stereotyping (Wenger, 1998). This is where participants make assumptions through imagining that practice occurs in a certain way or certain participants behave in a particular manner. Given that this research switched a particular group of students, the SDLs, into training and teaching roles, some of the teachers may have imagined that the SDLs would conform to a stereotype, with their conduct as that of a "typical" student, lacking professionalism or the usual standards expected of teachers and trainers.

Both imagination and engagement "create a … reality in which to act and construct and identity" (Wenger, 1998, p. 177). However, given that a CoP is "a matter of mutual

engagement" (p. 73), this becomes "a shared reality" (p. 177). In a similar vein, Wenger argued that imagination "is anchored in social interactions and communal experiences" (p. 178). As such, both imagination and engagement can be seen as social processes, not individual. This again suggests the value in analysing how teachers interacted with each other and with SDLs; what they said and what they perceived in reflecting on their knowledge and practice will give a better understanding of any development in their identities.

The final component to be understood in modes of belonging is alignment. This is a form of identity that is both in and across CoPs as it "bridges time and space to form broader enterprises so that participants become connected through the coordination of their energies, actions, and practices" (Wenger, 1998, pp. 178–179). This can be interpreted as members of CoPs doing something because it is part of a bigger picture, part of being a member of a wider community where it is understood that certain actions are part of a person's remit although they may not recognise, realise or fully understand the goal or aims or align themselves with the organisation they work for. Wenger (1998) described it more bluntly as doing "what it takes to play our part" (p. 179) and also highlighted that the lack of understanding or thought that goes into certain members' actions indicates that imagination is not a part of alignment.

Wenger (1998) went on to describe alignment in respect of the power that CoPs can have, with examples of where alignment is demanded and where members have "the power over one's energy to exercise alignment" (p. 180). This two-sided view on power does not focus on negative implications, however. There can be both positives and negatives that come from alignment and the power it represents. According to Wenger, there are possible trade-offs from alignment where alignment can "amplify our power and our sense of the possible" (p. 180). However, on the other hand, alignment "can also be blind and disempowering" (p. 181), where Wenger suggested that all manner of abuses of power can happen, which in turn can negatively affect identity.

The different elements of alignment discussed in this section point to how the teachers involved in the research study may not have understood the goals or aims of being taught by the SDLs or of the skills that were being taught. However, their alignment to the school's ethos and culture of providing empowering opportunities for students which leads to the work of the SDLs may have been enough to persuade them to align themselves to the project. In addition, the notion of trade-offs of alignment could be used to describe teacher actions in the CoPs observed. Any effects on their identities and how they were influenced by the SDLs can be analysed in light of this.

Modes of belonging is only one element of identity formation, however. According to Wenger (1998), "our identities form in this kind of tension between our investment in various forms of belonging and our ability to negotiate meanings in that context" (p. 188). Having identity as a cornerstone of Wenger's theory of social learning and understanding changes to teachers' identity during this research contribute significantly to be able to answer the research question. However, there remains the issue of how to interpret events, communication and actions during the project so that the lens of a CoP and the elements thereof serve their purpose. Understanding that identity is formed through a process of identification and negotiability provides some assistance in this regard. Thus, the next section will consider both identification and negotiability.

Identity through identification and negotiability

Wenger (1998) described identity as the coming together of identification through investment in belonging; and negotiability through working out the meanings of shared repertoire in a CoP. Identification is strongly related to the people within a community but also the elements of the community. As such, it was viewed by Wenger within the context of each of the modes of belonging previously described.

Looking at identification through engagement, Wenger (1998) said, "a lack of mutuality in the course of engagement creates relations of marginality that can reach deeply into our

identities" (p. 193). Applying such thinking to this research study suggests trying to answer questions as to how the teachers' views of their involvement in the CoPs would affect identity formation. Involvement is ultimately concerned with the concept of legitimate peripheral participation and how the peripherality of teachers in this study can be understood. This will enable judgements to be made on any changes to knowledge and practice.

The role of imagination and how this can be interpreted as perceiving roles in a CoP was described earlier, as were examples of how imagination could be significant in this research study. The significance was seen largely in how teachers perceive their roles as teachers and as learners developing skills in use of technology. This points to specific questions that need to be asked of teachers to ascertain these perceptions. However, there is a wider context for imagination that may be applicable in looking at identification through imagination. Imagination can be considered as a very broad concept that "depends on the kind of picture of the world and of ourselves we can build … the connections we can envision across history and across the social landscape" (Wenger, 1998, p. 194). Hence, there is a need to gain an overall sense of how the participants viewed not only themselves as teachers but also their past experiences in education, working with students and technology in various capacities. Having that information may enable better judgements to be made on the role of imagination.

Wenger (1998) talked about how "through alignment, the identity and enterprise of large groups can become part of the identities of participants" (p. 195). As already discussed, teachers may have aligned themselves to the work involved in the project and/or to the underlying ethos and culture of empowering students in roles such as those of the SDLs. However, identification through alignment "can take the form of concentration on a task, attention to details, or unwillingness to compromise" (p. 196). Observation of this in practice during the research was not anticipated to be problematic; however, issues of allegiance and compliance, authority and submission needed to be considered; hence, techniques to elicit that information after observation are vital.

Identification is not the only element in identity formation. Negotiability is also an element. In a similar way that identification is broken down into two equal parts, "negotiability is defined with respect to social configurations and our positions in them" (Wenger, 1998, p. 197). Labelling these as "economies of meaning" (p. 197), Wenger described them as where "different meanings are produced in different locations and compete for the definition of certain events, actions, or artefacts" (p. 199). In this research study, there were several opportunities for observing issues of negotiability. For example, events, actions or artefacts from the teaching and training that the SDLs provided may not have been given the same meaning by all teachers. Gaining an insight into the meanings that contribute to negotiability, such as in the examples provided, should be highly beneficial to seeing if there were any changes to teachers' knowledge and practice.

This section and the proceeding sections on CoPs have shown that the use of a CoP as a lens can facilitate understanding changes to the knowledge and practice of the teachers involved in this research study and if and how they were influenced by the SDLs they worked with. However, the focus has been on the theory of CoPs and elements of the theory which are pertinent to answering the research question posed in my research. This has served the purpose of understanding how to interpret events, communications and actions during the project; in other words, a lens by which to deduce influences on teachers' knowledge and practice from the data collected. However, it is also important to utilise this literature review to feature research perspectives where the theory of CoPs has been applied in situations where teachers attempted to integrate technology and in those where there was consideration of team-teaching factors. These directly relate to my research study. Through reviewing literature looking at similar issues, a broader view of how CoP can contribute to an understanding of how teachers' knowledge and practice developed while working with the SDLs. Hence, the next section provides such insight.

CoPs, technology integration and team teaching

In studies of technology integration in education, several researchers have observed a connection between TPACK and CoPs. J. B. Harris (2016) viewed CoPs as a TPACK development strategy, questioning what effective TPACK professional learning should look like. Marino (2009) called for pre-service teachers' preparation programs to involve the development of CoPs and the use of TPACK as a framework. The perspective of Murcia et al. (2018) was that "considerations of identity development and practice, a teacher's community of practice, enactment of digital technologies, challenges of mutuality and shared understanding, all impact on the development of digital understandings and TPACK" (p. 250). Hence, all these researchers have recognised the crucial role that CoPs play in developing and understanding TPACK.

The work of M. D. Phillips (2014) appears to have been an inaugural piece of research in respect of combining a CoP and TPACK. It provided an "investigation of the development and enactment of TPACK in workplace settings, implicitly recognizing the existence of TPACK as a form of shared practice embedded in context rather than knowledge held privately by individuals" (Jones et al., 2015, p. 3288). It supported the concept of distributed knowledge discussed as part of knowledge development in TPACK in Section 2.1. (Knowledge development in TPACK). However, also extended the concept of distributed knowledge by seeing TPACK among a group of teachers in a school as "knowledge that is developed in community and shared across a community of practitioners and … knowledge that appears to exist as current and as in development or under construction" (p. 256). Seeing knowledge through a CoP lens will thus influence how the teachers in my research demonstrated the TPACK that they developed, and are continuing to develop, how that was shared across the teachers involved and any influence the SDLs had on that.

In terms of understanding the relationship between a CoP and TPACK, M. D. Phillips (2014) provided case study insights that showed that despite being "in the same physical

context, the ways in which the participants enacted their TPACK were very different, and explorations of participants' practices and identity development helped to explain teachers' TPACK enactment" (p. 2). In other words, using CoP as a lens enabled evidence of teachers' "mutual engagement, joint enterprise, shared repertoire, trajectory and imagination … to explain teachers' TPACK enactment" (p. 246). These CoP elements, Phillips argued, redefine how context needs to be recognised in the TPACK model. As such, any considerations of context in my research study should take into account the core elements of CoP and how they shape a teacher's knowledge and practice.

Section 2.1. (Knowledge use and context in TPAC) reviewed literature specifically around context within the TPACK framework, and it is clear that there continue to be issues in deciding which factors should be considered influential, given a specific teaching and learning situation (S. Cox, 2008). It was also seen through the literature reviewed in that section that context can be identified at different levels and must consider both external and internal factors (Porras-Hernández & Salinas-Amescua, 2013). By examining context through a CoP lens, the intention of M. D. Phillips (2014) was not to dismiss the discussions, interpretations and points made as regards TPACK and context. Instead, it was to address the issue that research on TPACK and context "do not go as far as to indicate an appropriate theoretical lens through which context can be considered in teachers' knowledge development" (p. 110) and "Wenger's (1998) CoP framework may be suitable … as it links teachers' participation and identity within teachers' workplace contexts to their learning" (p. 110). Hence, the intention in my research study was to marry the TPACK and CoP lenses to understand teachers' knowledge and practice.

M. Phillips (2017) continued to use a CoP lens to understand how TPACK appears in practice. He viewed "identity to be considered as a socially mediated phenomenon" (p. 1780). As my research had teachers self-analysing their role, their confidence and skills in using technology and their relationships with both SDLs and with their peers, the use of a CoP lens enables TPACK to be seen from a communal perspective as well as from an individual

perspective, as described in M. D. Phillips (2014), M. Phillips et al. (2014) and M. Phillips (2017). The concept of "TPACK as knowledge in the making" (M. Phillips, 2017, p. 1793) also views TPACK as a fluid concept where the teacher's past and how they see their future role are factors that influence TPACK development. This viewpoint can be taken in the analysis of data in my research study.

However, perhaps the most salient point for my research study that M. Phillips (2017) made is in respect of team teaching and the concept of old-timers and newcomers that he challenged. He saw in his case studies that when teachers tried to improve the use of technology in their practice, there were relationships formed between "members at a midway point" (p. 1793). These relationships seemed to come about as a result of the reliance on certain teachers having better knowledge with technology, more TK or TPK, whereas other teachers were seen as more knowledgeable in other aspects of the TPACK framework. Thus, citing Lave and Wenger (1991), M. Phillips viewed relationships as moving from an old-timer/newcomer scenario to what "can be thought of as 'nearpeers'" (p. 1789). Highlighting how neither Wenger (1998) nor Lave and Wenger (1991) "discuss the differences in near-peer relationships compared to newcomer / old-timer relationships" (p. 1790), there was a focus on how team teaching can bring about working relationships, which may "be better thought of as near-peer relationships characterised by relationships of reciprocity" (p. 1790). The idea of exchanging ideas and sharing knowledge that reciprocity brings is an angle for analysing the data in my research to see how knowledge was used and shared by the teachers involved.

M. D. Phillips (2014) and M. Phillips (2017) recognised the significance of knowledge-sharing and reciprocity and how, in respect of TPACK, teams of teachers can take on different roles. Both research papers described that a CoP lens enables factors of mutual engagement, shared repertoire and joint enterprise to be considered as well as an in-depth understanding of identity formation through seeing TPACK as a non-static form of knowledge. Yet, despite there being 145 mentions of the word "student" in M. D. Phillips and

18 in M. Phillips, all of these refer to learning, engagement and working with or assisting students in understanding. There does not appear to be any consideration of the role students could take in influencing teachers' TPACK enactment or any influence they may have on teachers' identity and practice. My research intended to utilise the theories that were developed by M. D. Phillips and M. Phillips but extend these by examining any influence students in the role of SDLs may have had on teachers' knowledge and practice.

Support for the work of M. D. Phillips (2014) can be seen in academic research. From the perspective of Harris (2016), "workplace learning may be one of the most authentic forms of TPACK development" (p. 11), which she went on to suggest may be the result of "approaches for experienced teachers becoming increasingly situated and contextualized" (p. 15) due to the development of TPACK. However, Harris also signaled issues in using such a strategy as "its progress is challenging to document and to assist, due to differing interpretations and enactments of TPACK among and between the members of a professional community" (p. 11). M. Phillips et al. (2014) suggested that the way TPACK considers knowledge to be individual, rather than communal knowledge that can exist in team-teaching approaches, means that it is very limited when teachers work in team. They recommended the foundational elements of a CoP of mutual engagement, shared repertoire and joint enterprise espoused by Wenger (1998) need to be used to overcome such difficulties. This may not provide a solution to the "differing interpretations and enactments of TPACK" Harris (2016) pointed to, but it seems to support the suggestion that context (XK) is a highly significant element of the TPACK framework (Mishra, 2019). In respect of this research, considering the teachers' contextual knowledge, their mutual engagement, shared repertoire and joint enterprise will give rich contextual information for interpretations of data collected in this research study.

2.4. Literature review conclusion

In summary, the CoP framework provides a lens that allows for observing the

development of the SDLs and teachers collaborating in the technology integration process. The research question on understanding how the introduction of SDLs influences teachers' knowledge and practice from a CoP lens explores the interactions of SDLs and teachers as part of the school's professional learning provision and during team teaching in the classroom. This research intended to gain a better understanding of what happens in terms of such issues as relationships and power when students are actively involved in the technology integration process. Defining technology integration in education, scrutinising models for looking at teacher knowledge and practice in respect of integrating technology, examining perspectives on the active involvement of students and, lastly, establishing understanding of the school as a site of learning, a CoP demonstrates a gap in research in answering the question of *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?*

Chapter 3: Methodology

In the previous chapter, I closely examined the literature around TPACK and the CoP. The research looked at whether the introduction of SDLs; in other words, the active involvement of students in the technology integration process in a school, influences teachers' knowledge and practice. However, at the same time, using the TPACK model facilitates understanding of the ways in which different forms of knowledge impact on teachers' practice using technology and actively involving students brings in concepts of distributed knowledge.

Many different relationships and interactions developed in the school's CoP during this research, and the methodological approach needs to allow for close examination of these. It has been said that when scrutinising CoPs, one must "value the stories of the people involved" (Henderson, 2007, p. 76). Kayrooz and Trevitt (2005) highlighted the significance of examining the social environment of such communities. Johnson (2001) demonstrated the overwhelming popularity of the use of case studies in literature on CoPs. Although there have been a number of both quantitative and qualitative studies of TPACK, S. Cox (2009) recommended that "qualitative studies must include extended observation paired with interviews" (p. 69) with an understanding of participants' experiences and their interpretations when using technology. Accordingly, I deployed a qualitative approach allowing for a naturalistic study through a social constructivist lens of the teachers involved in this research. The following sections provide an explanation of the factors considered in implementing case study research.

3.1. Methodological approach: Case study

The overarching qualitative approach in this research was a multiple case study. Yin (2009) saw case study research as a method where the focus is on contemporary events, and the role of the researcher is to probe those involved with "how" or "why" questions. He provided a definition of case study research based on observation that "investigates a contemporary phenomenon in depth and within its real-life context" (p. 18). Yin (2003)

provided an example of when to use a multiple case study approach was for the study of schools adopting new innovations technology and/or curriculum based. Both of these align well with this research: to study students and teachers, in a real-life school, collaborating in areas of teaching practice involving the use of technology through a CoP lens.

The research design for this multiple case study

Using a multiple case study approach provides "a richer and stronger array of evidence that can be accomplished by any single method alone" (Yin, 2009, p. 63). The robustness of such an approach is evident from the implementation of case studies (Yin, 2009). The application of a multiple case study approach in this research consisted of the implementation of three SDL strategies in one school and the use of these as a basis for analysing the interactions between the SDLs and a group of teachers. The SDL strategies were designed to provide case study research opportunities through the study of teachers, working with students over a period of 6 months. I anticipated, early in this study, that each of the teachers involved would engage differently with the SDLs and there would also be differences in how they were influenced, depending on the approaches teachers were involved in. Some of the teachers were involved in more than one of the approaches, and likewise, some teachers did not partake in any or all of the strategies.

To fully understand the relationships and interactions in a CoP, the role, involvement and interactions of key stakeholders need to be analysed. For research design in a case study involving one organisation, establishing who the stakeholders are requires consideration of relationships both internal and external:

> Suppose you want to study a single organization. Your research questions, however, have to do with the organization's relationship with other organizations – their competitive or collaborative nature, for example. Such questions can be answered only if you collect information directly from the other organizations and not merely from the one you started with. If you complete your study by examining only one organization, you cannot draw unbiased conclusions about interorganizational partnerships. This is a flaw in your research design. (Yin, 2009, p. 27)

Yin's (2009) example emphasised that the school leadership are part of the research as well as teachers and the SDLs. Although the school is not really another "organization" as described by Yin (2009), it is very much an influential factor in what happens in a school. The school leadership play a vital role not only in developing technology integration (González-Sanmamed et al., 2017; Gülbahar, 2007; Leonard & Leonard, 2006; Vrasidas, 2015) but also in deciding who is employed, their roles and responsibilities and the culture and ethos of the school. Thus, they are key stakeholders and, as such, part of the investigation in this research study.

Knowing who to research in a case study methodology is only part of the research design issues that must be addressed. The data that is relevant, what should be collected and how to analyse it in light of trying to answer the research question are also of vital importance (Yin, 2009). Typically, research studies label gathering data as "data collection", but I am drawn to the views of M. D. Phillips (2014), seeing it as data generation where "amassing a data set is not a neutral process but actively involves authoring particular accounts, representations or versions of phenomena in particular times and places, according to particular epistemological positions" (p.124). Given this view, I generated data from multiple points of research, at different times within the SDL strategy, in different places, such as during teacher training sessions, meetings or in classrooms during lessons. The next section covers how I ensured that I took the best approach in this endeavour.

Data generation

Case study research "is grounded in deep and varied sources of information" (Hancock & Algozzine, 2015, p. 16). In other words, there are a number of sources of data available to researchers in case study methodology. According to Yin (2009), these may include looking at documentation, physical artefacts, interviews, direct observations and participant observations. A significant advantage of having multiple sources of evidence is the weight of the argument "if it is based on several different sources of information, following a similar

convergence" (Yin, 2003, p. 176), hence the significance of triangulating data sources. Given the need to include multiple data sources to provide opportunities for triangulation through converging lines of inquiry, the context of the research, what and who was involved as well as time restrictions, I considered it most appropriate to focus on a survey, participant observations and semi-structured interviews with both teachers and leaders in the school.

An outline of where and how the data was generated is presented below:

- *Survey*

Surveying the teachers involved provided a way to gather quantitative and qualitative data regarding their views and self-belief in areas related to both their own knowledge and practice, as well as the prospect of working with the SDLs. It was also a means of collecting some information about the teachers as individuals, such as number of years in the teaching profession and their areas of expertise. As questionnaires provide "structured, often numerical data, able to be administered without the presence of the researcher and often comparatively straightforward to analyse" (Cohen et al., 2018, p. 471), I provided a 19-question survey electronically to the teachers.

The planning and design of questionnaires are significant considerations in any research. The purpose of a questionnaire often guides its design; and, in this research study, the purpose was to establish foundational knowledge to guide the participant observations and the interviews. Given this basis and "a simple rule of thumb: … the smaller the size of the sample, the less structured, more open and word-based the questionnaire can be" (Cohen et al., 2018, p. 475), I designed a survey with a relatively informal and relaxed structure.

Many of the questions were of a multiple choice and/or ranking nature. These types of closed questions often enable analysis in the form of comparison between respondents (Oppenheim, 1992), which in this case was between the teachers. An example of the results of these comparisons can be seen in Table 3. However, as highlighted by Cohen et al. (2018), providing opportunities for respondents to follow up their closed question responses with

their own explanations is a strength in small-scale research. Hence, I provided these opportunities in many of the questions. Some of these explanations became talking points in the later interviews. The questions used in the survey can be seen in Appendix C.

- *Participant observations*

The major purpose of conducting participant observations in this study was to generate data related to the nature of the teachers' participation and engagement in their CoP. More specifically, the observations looked at how teachers:

- reacted to the SDLs in different environments, different situations; how teachers communicated with SDLs and with each other
- utilised resources created with or by the SDLs, which was very informative in respect of looking at the use of technology in teachers' practice
- shared teaching practice with the SDLs in the classroom, which provided evidence of whether teachers' knowledge and practice in respect of technology were being affected
- worked with the SDLs and each other in team-teaching situations.

Participant observations can potentially cause issues, particularly in relation to bias. As one of the senior leaders in the school used for this research, I, as the researcher, was clearly more than a passive observer. However, using a participant observation method allows the researcher to "assume a variety of roles within a case study" (Yin, 2003, p. 93). I did not take on the role of one of the teachers in the case studies but was involved in many different capacities within the research study. However, this did not eliminate the potential for bias as a participant observer. Given these dual roles, there is a need to examine bias in terms of my positionality and the ways in which I conducted research as a participant observer. This examination is provided below.

Positionality "reflects the position that the researcher has chosen to adopt within a given research study" (Savin-Baden & Major, 2013 p. 71). It influences how research is conducted as well as its outcomes and results (Rowe, 2014). An "open and honest disclosure" (Holmes, 2020, p. 3) is an important aspect of addressing bias in respect of positionality. Given this,

aspects of my positionality were first seen at the outset of this research (see Chapter 2, where I described the history of my involvement with the SDLs and the origins of this research). I also reflect on this to some degree in the conclusion in Chapter 10. Similarly, I informed the teachers involved in the research of my work with SDLs prior to the commencement of this project and my desire to have the SDLs working with them in trying to assist them in integrating technology. The focus of this study was not related to having success in working with the SDLs. It was concerned with trying to understand how SDLs influence teachers' knowledge and practice when that influence occurs. The teachers were made aware of this stance from the outset of this research, and I reminded them at various points, such as at the beginning of the interviews. Providing this clarity served to fully disclose my position and intentions in the research. Moreover, it informed the teachers involved that there was no pressure from the research, and from me as a researcher, to have them be positively influenced by the SDLs and improve in their knowledge and practice. I wanted a more balanced view and an understanding of how they were influenced, if it happened.

During the participant observations, I used passive observation techniques in that I observed the teachers working with the SDLs, "without conversing or interacting with their subjects in any way" (Brancati, 2018, p. 171). Brancati went on to describe the advantages with this approach, saying that, "researchers are unlikely to significantly change the behavior of the groups that they study by only observing" (p. 171). In contrast, during the semi-structured interviews described below, I was active, having direct engagement with the teachers in the study. This approach meant that during participant observations, I could passively collect evidence of the teachers' actions and dialogue with the SDLs. I could then discuss this evidence and ask the teachers to interpret it during their interviews, asking them questions, enabling them to provide explanations and reflections on what I had observed. This approach supports the practice of "clearly distinguishing…empirical observations from…interpretation of them" (Brancati, 2018, p. 181).

In summary, it has to be recognised that, as a researcher and a leader in the school, I could

not maintain objectivity throughout this study. The measures taken in respect of positionality described above sought to address issues of bias. Alongside this, I used a triangulation process where I made observations and checked answers to the survey questions with teachers during the interviews; and these became threads for parts of the interviews. Similarly, ideas and perspectives of teachers were shared with other teachers and leaders in the interviews. This idea of perspective triangulation (Denzin, 1978) provided opportunities to obtain different views on the work with SDLs.

- *Semi-structured interviews*

Semi-structured interviews involve questions about facts as well opinions related to events observed, the purpose of which "is to ascertain participants' perspectives regarding an experience pertaining to the research topic" (McIntosh & Morse, 2015, p. 1). Considered to be suitable for small-scale research, the concept involves having a general structure of the main questions, but finer detail is worked out during the interview, providing the interviewee with freedom of expression and a degree of control in being able to lead the conversation (Drever, 1995). Yin (2003) advocated for the use of semi-structured interviews as the technique "provides perceived causal influences" (p. 86). These "influences" and the flexibility described above were intended to permit more thorough investigation, particularly in respect of the issues of relationships and changing power dynamics between the students and teachers involved in the CoPs. The interview questions can be seen in Appendix B.

In this research study, the interviews were used to gather information on the following:

- teachers' views on working with the SDLs in different environments; how it affected their knowledge and practice
- teachers' perspectives and experiences regarding their participation and engagement in the CoP and their views on their own knowledge and practice in respect of technology
- teachers' reflections on working with the SDLs in team-teaching situations

- school leaders' perspectives on technology integration, the SDL concept in the school and any perceived effects of the schemes on teachers' knowledge and practice as well as on teaching and learning throughout the school.

According to Burns and Grove (1999), using semi-structured interviews has inherent risks, particularly in respect of over-reliance on one or a few respondents while not giving the same attention to other interviewees. Their suggestion, to reduce the risk of such imbalance, is to use alternative sources for confirmatory and contrary evidence. In the interviews, I asked for teachers' opinions and for their confirmation of what I had observed and interpreted. I then discussed their responses in interviews with other teachers. An example of this can be seen in the discussion about the SDLs providing a learners' perspective when working with the teachers. This was a comment made by a teacher during their interview. I shared this comment with other teachers in their interviews to ask their views on this.

In addition, as with participant observations, there is potential for bias. Yin (2003) pointed to the potential for poor question choices or leading questions by the interviewer, where the interviewee provides responses they perceive the interviewer wants to hear. To alleviate the potential for bias, firstly, I disclosed the aim of the research as the opening statement in each interview, reassuring the teachers that I was looking for their insight on their relationships and the interactions they had with SDLs. Leech (2002) championed questioning techniques such as floating and informal prompts. I used these liberally throughout the interviews to prompt elaboration and further explanations from teachers about the points they raised or the answers they gave. Coupled with very little use of closed questioning, I prompted teachers to offer their views and interpretations on their work with the SDLs. The interview questions were based on my observations when the teachers worked with the SDLs, what they said in answer to the surveys at the outset of the research and the views provided by other teachers. Having this design of interview questions reduces researcher bias as it offers a degree of respondent validity (Brancati, 2018).

Challenges in case study research

Although certain challenges have been detailed in respect of the data generation methods used in this research, there have been wider criticisms aimed at case studies in respect of validity, reliability and generalisability (Burns & Grove, 1999; David & Sutton, 2004; Yin, 2009). Addressing these criticisms in my research relied on accurately representing data and analysis from a qualitative perspective. This research study had to be more objective, more empirical and more rigorous than other research studies utilising more quantitative methods, as suggested by Freebody (2003). I employed two main constructs of research credibility, communicative validity and trustworthiness, to address validity and reliability as recommended by Freebody (2003) and Lankshear and Knobel (2008).

Definitions and descriptions of validity in academic research highlight differences in understanding and interpretation (e.g., see Freebody 2003). According to Lankshear and Knobel (2008), communicative validity is suited to case studies as it allows the reader to see the connections between a researcher's claims and their own experience or knowledge of similar circumstances. Lankshear and Knobel described strategies for ensuring the communicative validity of research. I adhered to these strategies where possible in this study, specifically in respect of cross-examination of data and checking for its accuracy, including interview transcripts, observation records and documentation. Accuracy of data relates to checks and verification of descriptions or representations with the participants involved. I verified the accuracy of my observation notes and transcripts with the teachers in the study.

In order for the reader to trust the researcher's methods, there must be transparency and clarity with respect to "the nature of … publicly knowable and inspectable procedures" (Freebody, 2003, p. 68). This allows readers to see how a researcher moves from research question to data analysis and knowledge is underpinned by sufficiency (Lankshear & Knobel, 2008). Sufficiency is having enough evidence to support claims and interpretations made in relation to the data and research questions (Freebody, 2003; Lankshear & Knobel, 2008). This

avoids tenuous analysis or claims being made in research (Fetterman, 2019). I collected large quantities of data in the form of survey data with 13 teacher responses to a 19-question survey, transcriptions of 10 interviews, 9 pages of observations notes and 18 recordings from 12 different events involving the teachers and students as part of the research as well as various pieces of related documentation providing a sufficient base from which to make trustworthy claims of knowledge.

The issue of generalisability in research is where "theories must be shown to account for phenomena not only in the setting in which they are studied, but also in other settings" (Gibbert et al., 2008, p. 4). Yin (2009) indicates that a common criticism of case study research is the inability of conclusions and findings drawn from one case study to be generalised to a broader population. He explained that researchers should "rely on analytic generalization" (p. 43). This is where the theoretical framework from a study is used to "establish a logic that might be applicable in other situations" (Yin, 2011, p. 18). In other words, if a case study researcher establishes a conceptual claim and then applies the theoretical propositions to generalise that in other similar circumstances, the findings will be the same.

The examination of data produced conclusions and findings illustrating that students were actively involved in the technology integration process. However, the intention was to leave wider interpretation of the contextual information that these case studies provide, to the reader. The onus was on me to use rigorous and clear research methods to produce sufficiently rich and detailed contextual information from which readers can make decisions on the relevance of the study to their own or other situations.

Writing one's own position into the research study is essential (McDowell, 1992). Regardless of the extent and quality of preparation for case study research, the whole study can be completely undermined "if an investigator seeks only to use a case study to substantiate a preconceived position" (Yin, 2009, p. 72). Case study research involves

understanding the issues that need addressing, in other words, the problems leading to the research questions. The risk of researchers not having a critical standpoint with regard to the possible outcomes of the research proposed is quite high (Yin, 2009).

At the school, there was a strong student voice culture, where students in active roles with teachers and students participated in some form of SDL role for 4 years prior to this research. To answer the research question, I have described the ways in which the SDLs were planned to be involved for, in Section 2.1. (The TPACK framework) and illustrated this in Figure 5. Some of the approaches to the involvement of SDLs and to teacher professional learning described in this thesis had previously been tried at the school. Given all this, there was a risk that, as a researcher, I came with a preconceived position and an expectation of the findings, as described by Yin (2009). As the researcher, my position was clear and repeatedly stated, in wanting to look at how teachers' knowledge and practice were influenced by the SDLs. However, given my position as a senior leader in the school and the history of my involvement in SDL schemes, the possibility of being seen to have a preconceived position exists. The measures taken, which I discussed in this section and the previous section on data generation, were intended to alleviate bias issues.

To reiterate, this research study was concerned with understanding how teachers' knowledge and practice may be influenced by the introduction of SDLs. Such foci, to date, have not been considered both in the school at the centre of this research study or in wider research. As a researcher who was also a school leader involved in the innovation of the SDLs working with teachers at the time of this research, I was cognisant of the need to constantly question potential bias in my research process and analysis. Yin (2009) argued that a test of "this possible bias is the degree to which you are open to contrary findings" (p. 72). The study investigated whether SDLs influence teachers' knowledge and practice, how it happens or the degree to which it happens. Hence, there was not a sense of expecting certain outcomes or outcomes that disprove pre-existing ideas. Thus, I maintain a critical standpoint with regard to the foci of this research and the findings of the case studies in answering the

research questions.

Summary of case study methodology

Despite the challenges in case study research, such a methodology "allows investigators to retain the holistic and meaningful characteristics of real-life events" (Yin, 2009, p. 4). This research study aimed to use Wenger's (1998) CoP framework as a lens to view any influences on teachers' knowledge and practice from the introduction of SDLs. Given Yin's much lauded work on use of case studies in research and the popularity of qualitative case study in research in a CoP, for example, Ange (2016), a similar method seems applicable. I have declared my position as both a researcher and leader within the school in the research but there remain potential issues, particularly in respect of what Flyvbjerg (2006, p. 234) described as "tendency to confirm the researcher's preconceived notions, so that the study therefore becomes of doubtful scientific value". Such a criticism of case studies, Flyvbjerg argued, are largely inaccurate: when researchers are transparent, they amass substantial data sets and analysis of data is thorough. Hence, it is with these factors in mind, that I used a case study approach.

To put this methodology into context, the approach in this research involved use of multiple case studies, with several teachers and multiple students providing a volume of data. Understanding the context for the proposed research is vital in a case study approach (Yin, 2009). Given this, the following section provided an overall picture of the setting of the school. This begins with a look at the school culture in respect of students in SDL roles, my role in regard to the SDLs, teacher professional learning, the views and the intentions of the school leadership and the shift to team teaching using a PBL approach.

The context for this case study

The setting for this research study was a state secondary school in South Australia. At the commencement of this work, the school had involved SDLs in various guises for over 4 years, seeking to empower them in a variety of roles with technology and had a strong culture

of student voice. It focused on teacher professional development and had a strong culture of "fostering genuine student voice" (Principal, personal communication, 2016). As a senior leader in the school, I had various responsibilities in respect of staff and students. This included organising and overseeing elements of professional learning, mentoring staff in the development of their professional practice and leadership over key areas of the school such as the STEM Program as well as overseeing students in a year group. Some of the students who took up SDL roles and staff who become part of the research study were also people I led, had responsibilities for or worked with as a senior leader.

Throughout the research, I was aware that I needed to pay particular attention to issues arising from being both a senior leader in the school and researcher. I was also conscious that by having such a vested interest in the school and the research, there was the potential for bias. Measures to address bias in this research are covered in Sections 3.1 and 3.2. Further measures to address potential for bias, but more importantly, to protect the confidentiality of the school, teachers and students are used throughout this research, resulting in the use of pseudonyms.

As a senior leader, one of my responsibilities was to engage students in the SDL program. Having been a feature of the school for over 4 years, the roles of SDLs had diversified as had my experience in setting up and organising the students in these programs. Thus, this research saw me in two roles: firstly, as the person overseeing the SDLs and their various roles in the school (see Figure 4); secondly, as a researcher collecting data from the case studies that I had set up.

At the beginning of the academic year in which this research study commenced, the SDL program had become relatively small due to existing SDLs graduating and a lack of focus on the program's development. There were only four students who regularly participated in activities, and much of their involvement was around assisting IT Support personnel, labelled as "technical leaders" in Figure 4. As the SDLs were a key aspect of the school's goals of

facilitating a student voice culture, my role as a senior leader saw me involved in inviting applications from potential SDLs in a number of areas. Figure 4 provides an overview of the intentions regarding SDL involvement in the school. The red boxes represent the title of the leadership roles they were involved in, the dark blue boxes represent the broad areas they worked in and the light blue boxes represent the sort of tasks that they were undertaking.

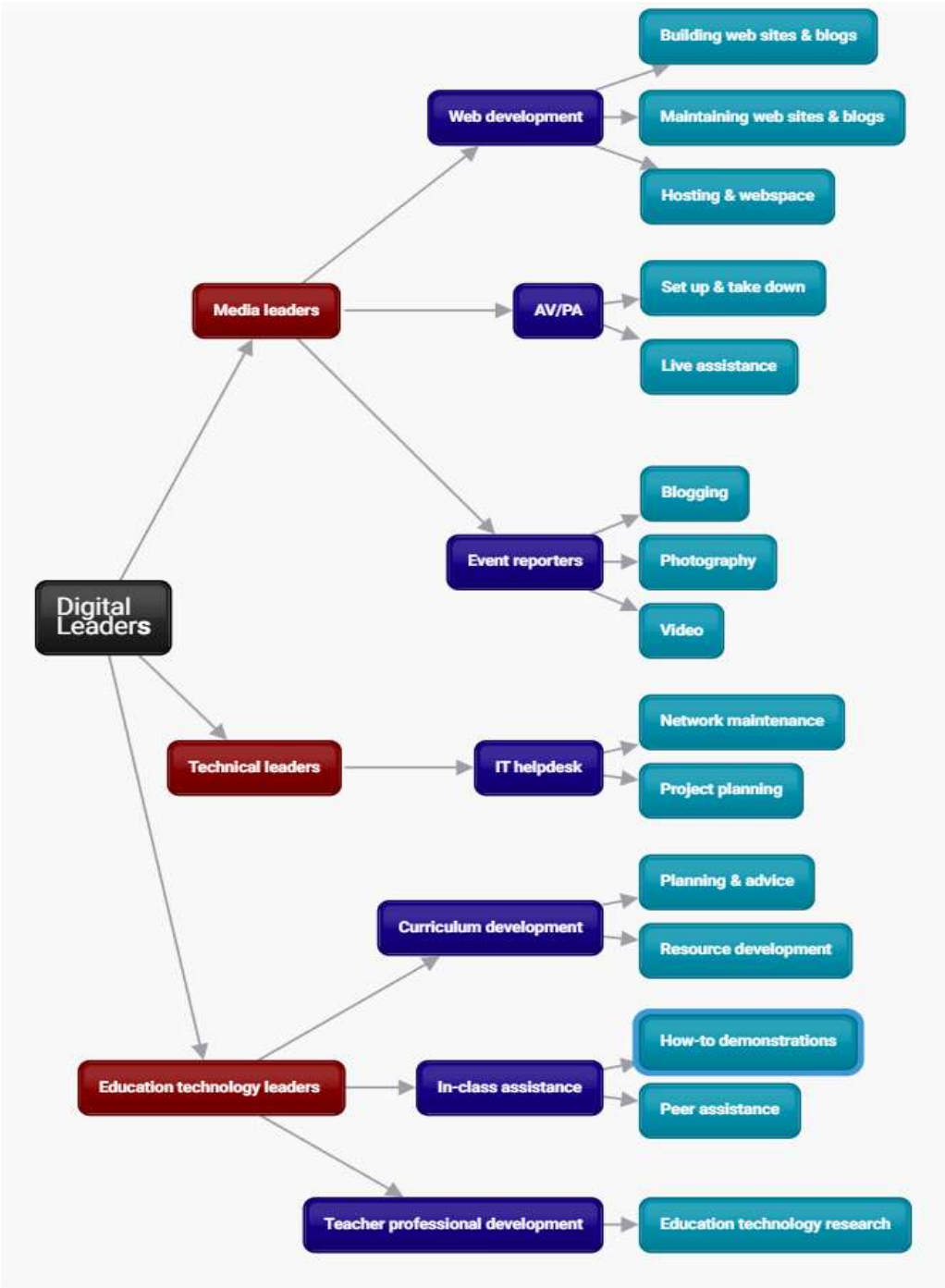

Figure 4: SDL scheme overview

Figure 4 shows plans for student involvement in a variety of roles related to the use of technology in the school. It also shows the school's commitment to empowering students in technology-related fields. Figure 4 goes beyond analysis for this research and beyond impacting on teachers' knowledge and practice. However, it does provide more information on the school setting and how students have been involved in roles in relation to technology.

Figure 5 focuses on the areas that were intended to provide data for this research study. Again, the red boxes represent the title of the leadership roles earmarked for SDL involvement, the dark blue boxes represent the broad areas for their involvement and the light blue boxes represent the sort of tasks that they could be pursuing.

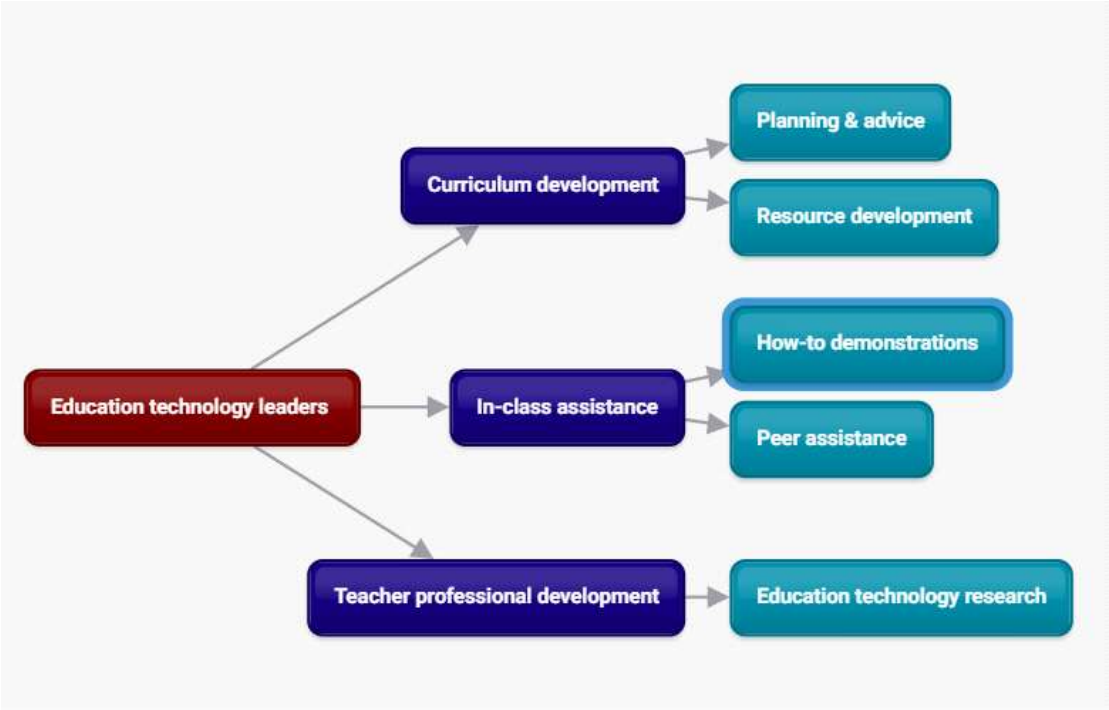

Figure 5: SDLs – Educational technology leaders

This research study provided professional learning to a group of teachers related to the planned roles and areas laid out in Figure 5. An overview of students' active involvement during the research study is described for each of the types of professional learning below:

Software training session – involving a small group of SDLs working with a large group of teachers on how to use a particular software tool. This was structured with both a

presentation to the group and hands-on workshop activities. The intention was to provide teachers with a chance to experiment and experience the software under the guidance of the SDLs who had already learned how to use it.

Pedagogical discussion session – involving a few SDLs working individually with small groups of teachers focusing on teaching and learning with 3D design software. This was structured as an open discussion where students and teachers could share views, ideas and experiences. The intention was to better inform teachers on student experiences of learning with this software and using it to design prototypes prior to teachers introducing the software to their classes.

In-class assistance – involving SDLs being placed in classes with teachers where they could, for example, demonstrate to students, assist students and/or the teacher concerned in respect of technology. This was very much left to teachers to organise with SDLs how they wanted to structure this and what specific roles they wanted SDLs to take in their classrooms.

The willingness of students to be involved in such projects was important as was choosing students to fulfil the SDL roles. In my capacity as senior leader, my role was to identify these SDLs and organise activities for them. I also had responsibilities for organising the school calendar to ensure the logistics for professional learning, such as indicated above, were in place. The activities involved exposing potential SDLs to upskilling in relevant IT tools, ensuring they had opportunities to practise presenting to audiences, assisting teachers and peers in different settings. Despite the challenges in developing this program and commitment of resources, it provided a significant contribution to the vision and focal areas for improvement in the school.

The vision of the school focuses on staff being innovative and passionate. At the time of this research study, there was a whole-school focus on quality teaching and learning which incorporated digital technologies. The “Site Improvement Plan” set out an action plan for the school in a 3-year period (Principal, personal communication, 2016). This shared the school

vision and detailed the use of technology in teaching and learning as an essential element of school improvement. The school's IT provision consisted of specialist Windows and Mac computers in particular areas as well as tablets that were loaned out for specific purposes, and all students were expected to bring their own device for learning. Staff used either their own device or a device provided by the school. The school had numerous traditional classrooms and an open space, the Learning Hub, with bookable zones supported by support staff and technology provision.

Staff in the school were provided with professional learning opportunities that align with the AITSL (2011) standards and formed part of the minimum of the 60 hours of professional learning that the National Professional Standards for Teachers (AITSL, 2011) requires each teacher to undertake. Four days per year were allocated as professional development, non-teaching days by the Department for Education and Child Development. Between two and three mentor sessions were provided each term with at least four professional development sessions, minimum 90 minutes in length, in each of the four terms. In addition, staff meetings and faculty meetings also provided opportunities for staff professional learning.

Professional development sessions at the school could take on many forms and cover a wide range of topics related to teaching and learning. It was common to have students involved in providing professional learning in using technology, particularly in TeachMeet style, short presentations that occurred at the end of each term. Likewise, two of the SDLs involved in this research study were well known and had been approached by staff at times to assist with technical questions and/or to assist in classes with technology. These students had also attended and presented at education conferences.

In the year prior to this research, a growth in student leadership had seen students involved in the school community in particular areas. They had been part of creating the "School Improvement Plan", attending course counselling events, providing insights on particular subject choices to younger students and planning for professional learning centred around

teaching and learning development under the Australian curriculum (Principal, personal communication, 2016). Thus, there was clearly a culture of working with students and giving them a voice and leadership opportunities in varying capacities, and this was driven by the school leadership team.

This research study focused on teachers involved in teaching the Year 8 PBL course, and the culture of student voice and leadership, of giving power to students, was a major factor in the introduction of this course at the school for 2017. PBL sees students given autonomy in their learning, where the focus is on student-centred projects being developed following themes guided by essential inquiry questions. This is an interdisciplinary approach to education, where in this case, social sciences, English, mathematics and science are not taught as standalone subjects but are interwoven within projects.

PBL also has a strong focus on developing particular soft skills in students, namely digital literacy and citizenship, critical and creative thinking, communication and teamwork. These, along with the emphasis on authentic problem-solving, given that all projects are driven by inquiry questions, culminate each term in students showcasing their learning through an exhibition of their work. The intention is for students to see connections between traditional subject disciplines and to facilitate a deeper understanding in their learning.

In order to introduce a PBL model 2017, during 2016, a group of teachers co-planned and attended professional development sessions. These sessions were largely led by the deputy principal. Regular meetings, planning sessions and further professional development continued during 2017 as these teachers prepared each term's theme. Some of these sessions involved all the PBL teachers in one whole group, but as the teachers were grouped together in fours to assist the co-planning process and paired together to team teach the program during the year, the teachers also planned in pairs and groups of four. All these teachers shared resources with the whole group through Google Drive; however, re-interpretation of the shared resources and the majority of co-development occurred within the pairs as they

attempted to prepare for their own classes and their students.

Not all teachers involved in the PBL program were involved in the planning in 2016, though. Indeed, some did not even join the program at the start of the 2017, commencing halfway through the year at the start of the second semester. As this research study occurred in the latter half of 2017, these factors are worth noting and are documented in Table 1. They will also feature as part of the case study discussions.

The theme of invention was the PBL focus during this research, where a design thinking methodology and its tools were used to address authentic problems introduced from community leaders, academics and industry professionals. This led students, some of whom needed to learn how to use 3D design software to 3D print their prototypes, to building prototypes. The SDLs became involved in the introduction, involvement and pedagogies around 3D design technologies, having input with both PBL teachers and students.

The focal point of this research was the teachers, though. Answering the research question requires an understanding of how their knowledge and practice were influenced by the SDLs. Hence, at this stage, I will introduce the teachers involved in the case studies and describe how they came to be involved. I will also illustrate the structure of their involvement in PBL and provide information as to how I gathered data from other influential sources in the school.

Teachers involved in the case studies

At the outset of this research, there were 15 teachers teaching PBL at the school. The teachers were grouped in fours. From each group, two teachers taught PBL classes in a team-teaching model. These PBL teaching teams and the influence of the SDLs are the focus of the case study discussions. Gaining an understanding of the relationships within these teams and between the teachers and the SDLs is the core element of this research. Discussions will look at how teachers and SDLs worked together as well as how the SDLs influenced teachers' knowledge and practice. To facilitate an understanding of the structure of staff involvement, grouping and teaching teams, an overview of the structure of PBL teaching groups and

leadership is shown in Figure 6 below.

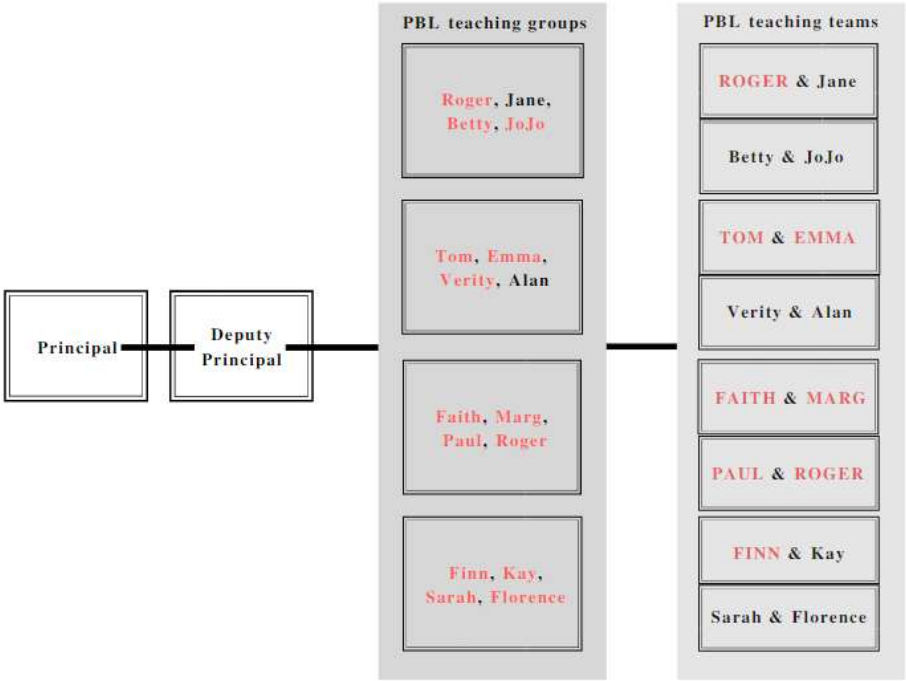

Figure 6: Teaching groups and relationships in PBL

Note. Black font – all teachers and senior leaders involved in the research at the outset; red font lower case – teachers who completed and returned an initial pre-involvement survey; red font in capital letters – teachers who were interviewed after working with SDLs.

In accordance with Monash University Human Ethics Committee approval of project: 8232, the PBL teachers listed in Figure 6 were invited to participate in the research project. Of those invited, 13 completed and returned an initial pre-involvement survey. These are indicated in Figure 6 with red font in the PBL teaching groups.

The survey was followed up with a session where PBL teachers were trained together on the use of 3D design software by four SDLs. The approach used in by the SDLs was a mix of demonstration and workshop where they showed teachers what to do and how to do it, then assisted the teachers in exploring the software and attempting designs. The next step after the software training session was a pedagogical discussion session where the SDLs were provided with opportunities to give their views on using, learning and teaching with the 3D

design software. After these two sessions, I offered teachers the chance to follow up with in-class assistance where the SDLs went into classrooms and assisted the PBL teachers and/or their students. In some cases, this meant the SDLs actually running sessions in lessons with the students. These events are depicted in Figure 7 below.

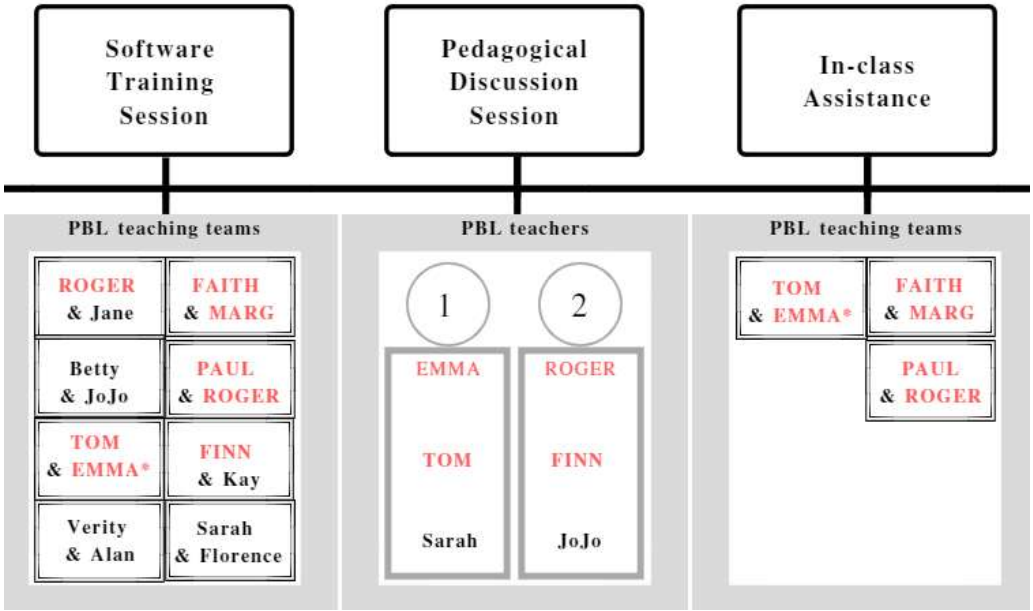

Figure 7: Timeline of key events involving the SDLs and teachers

Note. Black font – all teachers involved the sessions; red font in capital letters – teachers who were interviewed after working with the SDLs. Teacher with asterisk (*) – had a separate one-to-one software training session with a SDL.

Figure 7 shows a timeline highlighting the three key events described above and their order. Furthermore, it also provides details on the number of teachers involved, who they were and how they were organised, particularly in respect of the groupings in the pedagogical discussion session and which teaching teams had in-class assistance. A more detailed explanation of each of the key events and what is shown in the timeline in Figure 7 follow.

The initial software training session was organised for all PBL teachers at one time during a regular school day when teachers were removed from regular teaching responsibilities. All of the PBL teachers except one, who was absent on that day, attended that session. The absent teacher, Emma, highlighted by an asterisk (*) in Figure 7, later requested and had a one-to-one session with a SDL to be trained on the software. Although Figure 7 shows teachers who

attended the software training session as part of teaching teams were free to sit and work with whoever they chose. The use of the PBL teaching teams in Figure 7 links this timeline with Figure 6 and provides an understanding of who was involved in the PBL teaching teams and how those same people were involved in the software training session and in-class assistance.

The pedagogical discussion session was entirely voluntary and organised during lunch time, which created difficulties for some teachers in attending. Some chose not to attend, without citing a reason. Others had prior commitments and could not attend. Time pressures for teachers and SDLs alike prevented any opportunities for repeating the session to allow others to participate. The six teachers who attended were split into two groups with a SDL working with each group, as illustrated in Figure 7.

Having in-class assistance was, again, on a voluntary basis for the PBL teachers. Tom and Emma, Paul and Roger, Faith and Marg all had in-class assistance from the SDLs. However, there were also some teachers who did not have the SDLs involved with their PBL classes. For some, this was down to logistics, such as time and the availability of the SDLs. For others the reasons were less clear. When the SDLs assisted in PBL classes, planning and strategies for and with the SDLs regarding the exact role they would play were an issue; these are discussed in the case studies.

From the initial 15 teachers, seven became core participants in the research as they were involved with the SDLs in most or all of the sessions provided. They are indicated in Figure 6 and Figure 7 with their names in red capital letters in the PBL teaching teams. These seven teachers agreed to be observed, recorded and interviewed as part of the remainder of the research study. The observation and data from the pre-involvement survey combined with their reflections on working with the SDLs form the basis of the case studies detailed in Chapter 4. There are potential bias issues with such a selective sampling for the case studies as used in this research, and these are discussed in Section 3.2. (Understanding what data has been included).

In addition to the seven teachers chosen for the case studies, I interviewed the deputy principal and principal after all teachers had interviews. Their insight on how they saw the introduction of the SDLs influencing the teachers from a leadership perspective was intended to provide supporting evidence to what I witnessed in observations and discussed with the participating teachers. In addition, I asked them questions relating to the logistics of how the SDLs were organised to work with the teachers and how these factors played a role in any outcomes they witnessed.

Table 3 provides demographic details for a better understanding of the teachers who became core participants.

Table 3: *Core participant teachers' demographic details*

Name	Years teaching	Years teaching at the school	Qualified to teach in	Role in school	Experience in PBL	Involved in PBL planning	Joined PBL team
Tom	6	5	Humanities, Research Project, PBL, English, Special Education	STEM Transition Program Lead Teacher, Teacher	No	Yes	At start of 2017
Paul	4	1	Science, Maths	Teacher	No	No	Semester 2
Emma	20	1	English	Teacher	No	No	At start of 2017
Roger	35	9	Chemistry, Physics, Maths	Teacher	No	Yes	At start of 2017
Faith	2	1	English, Health	Teacher	No	No	Term 2
Marg	1	½ year	Humanities, English	Teacher	No	No	Term 4
Finn	4	1	Maths	Maths & Science Coordinator & Numeracy Leader	No	Yes	At start of 2017

Table 3 shows that some of the teachers taught the same subjects outside of PBL; that is, they were part of the same subject faculty. However, as shown in Figure 6, those same teachers were in groups and teams with teachers not in their faculty. Given this information, the PBL teacher groupings and team-teaching pairings, the teachers could be said to have been involved simultaneously in various CoPs in the school.

Wenger (1998) highlighted the idea that people "participate in multiple communities of practice at once" (p. 105) as, "potential of creating various forms of continuity" (p. 105) among the CoPs. Thus, in essence, there is the probability that the teachers in this study were taking practices and using resources from one CoP to another. This process of brokering and boundary objects being reified needs to be recognised as it may have influenced the teachers' knowledge and practice and hence the outcomes of this research.

While recognising the influence of brokering and boundary objects, the connections and the effects that CoP multi-membership on this research, the focus here is on specific teachers. The information provided in Figure 6 and in Table 3 gives further context for the reader. In doing so, it highlights the restraints in size and scale of the study. However, given the scope of the research and what was achievable, these limitations provide for a thorough analysis of their knowledge and practice and how they have been affected by the introduction of SDLs.

This section has provided the context of this research: the setting, the culture, some history in respect of student leadership and voice activities in the school, information on how teachers' professional learning was approached, the introduction of PBL and the teachers involved. In other words, it set out the foundations needed for the study to occur. Answering the research question *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?* involved trying to "understand a real-life phenomenon in-depth" (Yin, 2009, p. 18) with a focus on collecting and analysing qualitative data. This is explained in the next section.

3.2. Data analysis

Analysis of qualitative data is a process of transformation and interpretation (Richards & Morse, 2012). However, such a process is far from simple, as “it is easy to be overwhelmed by the volume of data” (Seers, 2012, p. 2). As already discussed, there was a considerable amount of qualitative data collected; therefore, the challenge is in ensuring that data is analysed and processed to represent the findings appropriate to answering the research question. An “unethical case writer could so select from among available data that virtually anything he wished could be illustrated" (Guba & Lincoln, 1981, p. 378). Thus, in this section, it is imperative that an explanation is provided as to the processes used to unpack the data, how the lenses were utilised and why some data was used and some was not.

Coding iterations as a narrative around the analysis of data

Unpacking the data was an iterative process. With survey data from 15 respondents, 31 audio recordings and observation notes from three individual professional learning sessions and six lessons as well as 10 interview transcripts, analysis of the data was a challenge. However, it was not only the amount of data requiring analysis that was an issue as analysis requires “detailed work and reflection” (Seers, 2012, p. 2) where the researcher needs to provide a balance between immersion and objectivity. There is a smorgasbord of strategies that can be used when analysing qualitative research data, where it is important to recognise that the goals of a researcher can become a source of bias as they influence the way they interact with the data (Bazeley, 2013).

A strategy evolved in unpacking and analysing the data, looking at whether inductive or deductive coding techniques were most appropriate. This approach, and all subsequent approaches to coding, were facilitated by NVivo version 11 software. I imported and manually coded all the collected data in trying to answer the one, main research question *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?* With this and the focal areas detailed in the literature

review providing a lens to enable the answering of that question, it would seem natural to have those same foci guide the analysis of collected data. That was, indeed, the starting point in analysing the data, where after initially feeling unsure as to how to go about data analysis and the coding process, I realised that this is a common issue, namely deciding on different types of coding – inductive versus deductive (Hsieh & Shannon, 2005). Such an iterative approach is an important part of the process, which promotes confidence in the findings (Yin, 2003), and the use of deductive approach was the foundation of the first iteration.

Deductive reasoning can be a useful approach for qualitative research, particularly in the early stages of data analysis (Berg, 2004), where a researcher is looking to prove particular theories. Given this, themes from my literature review provided those theories, namely technology integration, critical pedagogy and the CoP framework. I then further distilled them to produce specific information sought in the collected data, that is, the codes. Hence, the codes were, in essence, a label given to a specific element of data (Coffey & Atkinson, 1996). These labels became the codes. The basic coding process was intended to organise large quantities of text into more concise and manageable content (Weber, 1990). Such a coding process facilitates the finding of patterns or themes (Hsieh & Shannon, 2005). Thus, on application to the coding process described, the codes were intended to provide thematic or categorised evidence to support the theories highlighted by the literature review.

However, during this deductive process, I became disenchanted by the outcomes in respect of answering the research question and moved into coding that involved elements of inductive and deductive reasoning, an approach that can be beneficial in data analysis, according to Wildemuth (2016). However, I found that this highlighted situations where the SDLs were influencing teachers' knowledge and practice, rather than an analysis of how that was happening. The issue of how was the focal point of the research, as it provided an insight not only into what happened during the SDLs' involvement with the teachers but also how it happened.

I carried out a third iteration to try to understand how events happened during the research. This had greater focus on specific areas and an attempt to look for patterns and relationships in the data. The survey, Pre-involvement of students in the training program, provided a starting point for an examination of how the teachers involved perceived their views on using technology in the classroom, their skills and confidence in these areas. Self-reported confidence and experience were also something that I discussed with teachers in the later interviews, and hence provided a way of looking at the similarities and differences between the teachers when I analysed the interview and observation data. Analysis of the data from the survey, the interviews and observations provided some sense of the teachers' knowledge, practice and confidence before their involvement with the SDLs, during the research study and on reflection afterwards. This combination of survey data, observation notes and comments made in the interviews provided a basis to enable an attempt at answering the research question. It was from this third iteration that the case study approach, described in Chapter 4, was largely developed. The role of the lenses was a significant aspect of this research, however; the next section provides details in this respect.

The role of the lenses in the analysis of data

Forming case studies to represent data findings cannot be effective without consideration of the lenses used to analyse data in this research, namely the CoP and TPACK. These lenses offered perspectives to look at complicated problems, focusing on different aspects of the data and providing a framework within which to conduct analysis (Reeves et al., 2008). Some alignment to the TPACK framework can be seen in classifications used in the third iteration of the coding in the section above where the focus is on knowledge and practice, but far greater use of the TPACK lens is needed, and the case studies will provide that.

The CoP offered a lens to observe the development of the students and teachers collaborating in the technology integration process. Elements such as relationships and power, identity and the roles that both students and teachers play formed a major part of these

case studies. Recordings and observations during professional development sessions, lessons and in conversations, provided threads for the interviews. During the interviews, the teachers reflected on observations I had made of their interactions with the SDLs. These reflections were then used to get a fuller understanding of what was happening and how. All of these data elements depicted the development of teachers' knowledge and practice over the course of the research study, which enabled the case studies to be formed.

Understanding what data has been included and sampling bias

The coding process undertaken in this research was described in Section 3.2. (Coding iterations as a narrative around the analysis of data). The teachers who participated were identified in Section 3.1. (Teachers involved in the case stuies) and their involvement illustrated in Figure 7. Figures 6 and 7 also provide clear indication of who was selected as subjects for the case studies, namely Tom, Emma, Faith, Marg, Paul, Roger and Finn. However, these also highlight which teachers were not selected, which could be seen as providing a biased sample; explanations are required to eliminate such views.

Sample selectivity bias has been described as "when the available data sample is truncated according to the value of some variable correlated with the dependent variable" (Hashimzade et al., 2017, p. 78). Although taken from an economics context, this view relates to how a decision over which data to include and/or not include can be purposely made to prove a point in research. The coding iterations described in Section 3.1. (Data generation) are provided to give not only an overview of the coding process undertaken in this research study but also details of how it was an iterative process – a process of discovery to decipher how best to interpret the data collected in order to answer the research question. Through this process, I discovered how the use of inductive and deductive reasoning led to seeing the pre-involvement survey as a foundation for analysis of the teachers involved. This then led to an analysis of the data from the interviews and the observations relating back to the views expressed by teachers in that survey.

The teachers selected for the case studies were those who participated in most, if not all, the stages illustrated in the timeline in Figure 7. In other words, they were heavily involved in working with the SDLs and hence, I could observe, record and question them in the interviews regarding this involvement. They were also diverse in nature when looked at through a CoP and TPACK lens as they had a wide range of experience, self-reported skills and confidence in using technology in their practice and a similar breadth of experience as a teacher. According to Merriam (2009), "sample selection in qualitative research is usually (but not always) nonrandom, purposeful, and small, as opposed to larger, more random sampling in quantitative" (p. 16). The teachers who featured were not randomly selected. They were selected to provide a small, contextual sample which can be thoroughly interrogated to answer the research question.

There is also a risk in case study research that through a lack of structure and focus, it is easy to lose sight of the purpose of the study, namely to answer the research question(s) (Yin, 2003). Including only details that have relevance to the findings is an important consideration (Bassey, 1999). To address issues of structure and focus, Yin (2003) advised that case study research should frequently reference the question and consider the theoretical standpoints emanating from the literature review.

Similarly, when amassing volumes of data, it is vital that actions are taken regarding issues of authentication and ensuring the data included in the research represents an accurate response to the research question. These came in the form of data being analysed from different perspectives at various times and locations within the project. I also sought verification from the participants of my assumptions and deductions. Such triangulation and authentication methods coupled with a desire as a researcher to be "casting off preconceived notions and theories" (Flyvbjerg 2006, p. 239) were measures put in place to provide authenticity to the findings.

Given this advice, the case studies presented were centred on analysing the data through the lenses of CoP and TPACK, with continual reference to the teachers' knowledge and practice, with verification of any assumptions made. Explanations are provided to link research with evidence that the data produced. Research with evidence is structured through the case studies.

3.3. Methodology conclusion

The Methodology chapter has provided an overview of and reasons for the qualitative case study approach. It has detailed the context of this research and my positionality in the study. This is intended to give the reader an insight into the environment and culture of the school and the participants in the research. Aligning with the view that one ought to be seeing such work as research practice, "focusing on the practice of research, on how research unfolds" (B. Green, 2015, p. 6), the chapter has discussed coding issues and the development through coding iterations to give a perspective on attempts at analysis, which led to the findings discussed in the case studies below.

Chapter 4: Case studies

4.1. Case studies introduction

As indicated in Section 3.1. (Teachers involved in the case studies), seven teachers made up the core participants of this research study as they completed the initial survey, took part in most of the sessions with the SDLs and provided reflective interviews on their involvement in the process. These seven teachers are shown in red capital letters in their roles as members of the PBL teaching teams in Figures 6 and 7.

Figure 7 provides an overview of the way key events in this research study were organised with data collected at the software training session, the pedagogical discussion session and the time when the SDLs provided in-class assistance. Table 3, particularly the "Role in school" column, shows how teachers were involved across the school; however, it also shows that they had roles as subject teachers in various faculties, specialisations, non-subject specific responsibilities and experience. It could be argued that there were many opportunities for potential membership in different CoPs throughout the school for these teachers, and as can be seen in Figure 7, they did not always work in their teaching teams at each point of data collection. This offers certain dilemmas in how best to present discussion around findings from the data, in other words, how to structure the case studies.

Having a case study for each individual teacher provides opportunities to consider each teacher's identity and trajectory and look at how their knowledge and practice were influenced during each phase of the study. However, through analysis of the data and coding patterns, many discussions focusing on teaching teams as well as providing opportunities to look at individuals are needed. There is a lot of rich data which helps in answering the research question in terms of practice. This data comes from events during the in-class assistance phase, when SDLs worked with teachers. Hence, there was a need for a means by which both teaching teams and individuals could be discussed through the lenses of TPACK and the CoP. Given this, the ideal seemed to be a structure where each case study consisted of a teaching

team, and under each of these, subheadings exploring theoretical and thematic concepts. Under some of these subheadings, teachers could be discussed individually, while, at other times, in teams. Structuring the case studies in this way provides opportunities to look at any influence the SDLs had on each teacher's knowledge and practice and how that happened within a team-teaching approach.

An overview of the structure of the case studies that will follow in Chapters 5, 6, 7 and 8 is:

- Four case studies are provided in separate chapters. Each case study features a teaching team except the final case study that features one of the teachers from a teaching team
- Within each case study chapter, there is-
    - A short introduction that provides insight into the teachers involved and what the main points of discussion will be.
    - Discussions under sub-headings
    - A conclusion that brings together discussion and analysis from each case study

However, before launching into the case studies featuring each teaching team, some of the collected data from self-reported views and teacher reflections can be viewed as a whole. These were intended to enable certain patterns to be seen that could be analysed in respect of knowledge, practice and context and provide further foundations before looking at the case studies.

4.2. Self-reported views and reflections

An overview of the teachers, their views at the outset of this research study in relation to digital technology and in relation to experience working with the SDLs was achieved through

analysing responses to a pre-involvement survey. This focused largely on how the teachers saw their skills and experience. It featured teacher views on using technology in their practice and a sense of confidence or lack of confidence in this respect, going into this research study. The responses are presented in Table 4.

Table 4: *Teachers' self-reporting on technology and experience working with the SDLs*

Name	Areas of knowledge and practice					
	*Views on use of digital technology in teaching practice?	**Confidence generally in using digital technology as part of teaching practice	**High skill level generally in using digital technology as part of teaching practice	**Looking forward to working with SDLs	Previously been trained in use of digital technology by students	Previously had in-class assistance from SDLs
Finn	5	4	2	5	No	Yes
Tom	5	4	5	4	Yes	Yes
Emma	3	2	2	5	No	No
Faith	4	3	3	4	No	No
Marg	5	2	2	5	No	No
Roger	4	4	3	3	Yes	Yes
Paul	5	4	4	4	Yes	Yes

It should be acknowledged that there is the potential for bias in these self-reported views, given I, as researcher, administered the survey. However, Table 4 provides some insight into the research participants' views, experience and how they saw themselves in areas related to the focus of the research, namely working with students and teaching with digital technology. As Wenger (1998) saw that "identity in practice arises out of an interplay of participation and reification" (p. 153), this data presents a means by which the participants can be understood in terms of elements of their identity at the outset of the research.

From a CoP perspective, considering the teachers' perceived knowledge and experience also goes some way into understanding their identity in respect of this research study, particularly when analysed in light of the information provided in Table 3 regarding their experience in the profession and at the school. The central premise in Wenger's (1998) social theory of learning is "Knowledge is a matter of competence with respect to valued enterprises" (p. 4). For Wenger, experience and competence are constituents of knowing for

learning in practice to exist, “this two-way interaction of experience and competence is crucial to the evolution of practice. In it lies the potential for a transformation of both experience and competence, and thus for leaning, individually and collectively” (p. 139). From this perspective, there is clear potential for experience and competence to drive the evolution of the teachers’ practice during this research study, which in turn transforms their identity. Thus, the data in Table 4 provides a starting point for presenting the case studies and the participants.

Table 4 shows that four of the seven teachers believed that they should maximise any opportunities to use digital technology in their practice. Two of the remaining three teachers believed that they should use it “a lot” (4 on the Likert scale for that question). The data also shows their positivity in looking forward to working with the SDLs. In both these questions, there were instances of a response below the top two scores, but it was a different teacher each time: Emma in respect of technology and Roger in respect of working with the SDLs.

The questions with the largest variance in the answers are “Confidence generally in using digital technology as part of teaching practice” and “High skill level generally in using digital technology as part of teaching practice”. In both of these, there was more than one teacher who saw themselves as low, but nobody chose 1, the lowest score. Similarly, in both of these questions, there was one teacher who ranked themself at the highest level on the scale, although again this was not the same teacher. Similar mixed responses appear in the two yes/no questions regarding having been trained in the use of digital technology by students and having had in-class assistance from the SDLs.

Providing a quick summary of the Table 4 data is intended to show that there was wide variety in the participants, a cross-section of different experiences, skills and confidence. As indicated in Section 3.2. (Understanding what data has been included), the choice of which teachers would participate in the case studies was not random. After volunteering to be part of the research, the teachers were chosen as is typical in case study research, according to

Merriam (2009). This highlights the strength of the case study subjects in being able to substantiate evidence in respect of answering the research question as it aligns with what is expected in multiple case study research, namely to explore within and between cases (Yin, 2003). It also aligns with Yin's (2009) reasoning on when to use a case study approach; as this research study was concerned with a "how" question, the focus was on the behaviour of the research subjects and there was great significance in the context. Thus, having a wide range of participants with interconnected relationships, similarities and differences within the context of the SDLs working with the teachers provides a broader understanding of how the SDLs influence teachers' knowledge and practice.

The data from Table 4 provides strong foundations for this research study as it introduces the participants individually, it describes their identity at the start of the research as a teacher in the CoPs around the PBL teams and groups as well as their thoughts on working with the SDLs and previous experience of working with SDLs. By looking at these individuals, we can get a sense of their identities from the outset. At the same time, though, particularly due to the variances in the way the teachers viewed themselves in respect of skill and confidence, presenting the data in a tabular format provides an overview of the range. Having such a spread of teachers with different confidence and skill levels provided opportunities in the reflective interviews to ask specific questions to see whether working with the SDLs had brought about any changes in the teachers' knowledge and practice, in other words, a chance to utilise a TPACK lens. Responses to these specific questions have been analysed and judged to be positive, neutral or negative, enabling the summary of data shown in Table 5 below.

Table 5: *Teachers' self-reported views on the SDLs affecting knowledge and practice*

Name	Areas of knowledge and practice			
	Confidence generally in using digital technology as part of teaching practice	High skill level generally in using digital technology as part of teaching practice	Do you think your knowledge & practice have advanced in respect of this particular software as a result of being trained by the SDLs?	Do you think working with the SDLs has also more broadly affected your knowledge/skills/confidence in using technology in your teaching practice?
Emma	2	2	+	+
Marg	2	2	+	+

Faith	3	3	+	=
Finn	4	2	+	+
Roger	4	3	+	+
Paul	4	4	+	-
Tom	4	5	+	-

Note. *Scale used - 1 = lowest to 5 = highest; ** Scale used - + positive, = neutral, - negative.

Table 5 features the teachers' survey responses on confidence and skill levels in using digital technology at the outset of this study with answers to relevant, follow-up questions from the reflective interviews. Coding these answers provides a quantitative overview. Sorting from low to high in respect of self-reported confidence and then, when values are the same for confidence, sorted low to high by skill level for each teacher in the study, has been included simply to enable easier viewing of the spread of confident and skilled teachers in order.

From Table 5, we can see that all seven teachers answered positively to the question of whether involvement of the SDLs enhanced their knowledge and practice in respect of a particular software application that the SDLs assisted with. This data can be considered in respect of context in the TPACK framework represented by the outer circle in Figure 2. Furthermore, through the definitions of micro, meso and macro levels of context described by Porras-Hernández and Salinas-Amescua (2013), arguments can be made for how the SDLs impacted the TPACK of teachers involved. Given this, Table 5 data indicates that having students actively involved with the teachers in technology integration may be considered a beneficial micro-contextual factor in shaping teachers' TPACK. However, at a meso level, the contextual impact on teachers' TPACK – knowledge/skills/confidence in using technology in their practice – was more varied.

Paul and Tom self-reported the highest combined skills and confidence levels when compared with the other five teachers (Table 5). The only two negative responses to the reflective interview questions came from these two teachers at the meso-contextual level. In the reflective interviews, Paul commented that he was "pretty digitally literate already", and Tom's reply was "No, I don't think it did and I say that because I kind of had a grasp before

and I think I still have a slightly better grasp than they did". These responses suggest that they both saw a link between their own skills and confidence levels in using digital technology in their practice and what the program could add. Whether their views were directly related to the program being led by the SDL and whether those views would be different if the program involved other teachers or professional trainers is unclear.

Faith judged her skill and confidence levels in using digital technologies to be somewhere around the middle of the scale (Table 5). She offered what is represented as a neutral response in respect of the impact the SDLs had on her TPACK at a meso-contextual level. Her comments in the reflective interviews provide some perspective on her response, however, where she said that working with the SDL "has reconfirmed some uncomfortabilities that I have had, always". She followed this up by saying, "If anything, it's made me just a little bit more aware of how, much more training that I do need or more focus I do need to have on that area of my teaching". Such comments could shift views on the neutrality of the SDLs' impact on her TPACK as they can be interpreted as the SDLs having had a positive effect on her contextual knowledge (the outer circle of the TPACK framework in Figure 1), given that it highlighted her lack of confidence in using technology and the need for retraining.

Analysis of the data in Table 5 suggests that although working with the SDLs had some positive contextual effect on all teachers who participated, for those who self-reported lower confidence and skills in using digital technologies as part of their teaching practice, the influence was more widely impactful. Hence, it could be argued that there was a link between the self-confidence of the teachers and the degree of impact that SDLs had on TPACK. Connections between teacher confidence, self-efficacy and TPACK are not new phenomena. Porras-Hernández and Salinas-Amescua (2013) saw context as "not only externally given conditions that influence or determine teachers' practice, but also objects of knowledge that the teacher learns to interpret" (p. 228). Given this, application of TPACK requires answering questions on what teachers know at various contextual levels and how that influences them in integrating technology into their practice. This is provided for this research study by Table 5.

Having data from the teachers on self-confidence and self-reported skill level at the outset of this research study provides valuable context when looking at how the same teachers believe they were influenced by SDLs after working with them. The way data is presented in Table 5 allows for judgements to be made, one of which is that SDLs had more impact when teachers were less confident. However, at the same time, this data, along with the Table 4 data, provides an initial understanding of how the teachers viewed themselves going into the research and what they thought was the impact of the SDLs.

This section has been constructed to contribute to answering the research question through exploration of a teacher's initial identity, knowledge and practice from a CoP perspective and in relation to TPACK. In essence, this research study was an attempt to understand how the introduction of SDLs leads to (or does not lead to) changes in teachers' knowledge and practice. Understanding changes to teachers' knowledge and practice when using technology can be attempted using a TPACK lens. However, because this research was intended to analyse seven teachers with various roles, responsibilities, experiences, identities and, ultimately, practice, operating in teaching teams, using a CoP lens is advantageous as it allows a focus on how individual trajectories and identities are related to team-teaching practice evidenced during the study.

Table 5 provides a beginning and an end point for this research. However, it is a simplistic overview at this stage, particularly as the teachers featured in the case study were involved in more than one activity working with the SDLs, which generated far more elements of data contributing to understanding the influence of SDLs on the teachers through both a TPACK and CoP lens. Table 5 does not give insight into how the introduction of SDLs influenced teachers' knowledge and practice. Hence, following the teachers over time through case studies was a conduit to answering the research question.

By following the teachers' activities through a CoP lens, looking at what they were involved in, what they said and did, the trajectories of each of the teachers can be seen.

According to Wenger (1998), trajectories have “a coherence through time that connects the past, the present, and the future” (p. 154). In other words, there is a need to understand the history of the teachers involved as well as their anticipated futures. Having an overview of the teachers and their demographic details in Table 3, supplemented with Table 4 and Table 5 data, provides the foundations for enabling such a process. From this position, the case studies can be constructed with each teaching team providing an opportunity for discussing both individuals and the team as a whole and enabling an in-depth analysis of how the SDLs influenced teachers’ knowledge and practice.

Chapter 5: Case study 1 – Paul & Roger

This case study focuses on two teachers, Paul and Roger, both teachers in the school's science and maths faculty. Paul was a new staff member, having been appointed at the beginning of 2017, the data collection phase of this research project. In contrast to Paul's recent introduction to the school community, Roger had been teaching there for 9 years. As a newcomer, Paul was paired with Roger to form a teaching team for the PBL program as "Roger could get Paul up to speed from what he had done as part in planning for PBL and they were both Science" (Deputy principal, interview, 8 December 2017). I recognised from the outset of PBL teaching that, as an old-timer, Roger had prior knowledge of the intended enterprise at a school level as a result of his involvement in the planning stage. This pairing is very much in the spirit of Wenger (1998), and while these descriptions of Paul and Roger as newcomers and old-timers appear accurate, analysis of the data in this chapter will reveal tensions which challenge such labels.

In addition, the deputy principal seemed to suggest that as Roger and Paul also taught the same subjects, Roger could offer some insights into the ways in which science teachers worked together in the school. As reported in other studies of CoPs in schools, CoPs do not necessarily form naturally as a result of teachers working together or learning together (Akinyemi & Rembe, 2017; Brouwer et al., 2012; Patton & Parker, 2017). Hence, the mere fact that teachers are engaged in teaching content from the same subject area does not constitute a CoP; however, the deputy principal appeared to suggest a likely closer connection between two teachers working in the same faculty than teachers from different faculties. The potential to develop closer working relationships as a consequence of sharing repertoires of practice and engaging in negotiated enterprise suggests the potential for a faculty-level CoP. By putting them together in a teaching team, there were further opportunities to develop a CoP due to the shared responsibility of teaching their PBL class.

This case study looks at the significance of identity through imagination and trajectories of

Paul and Roger through a CoP lens. Identity is shown to affect the roles that teachers negotiate in a teaching team comprising of two teachers with different levels of experience. How these teachers participate due to these roles influences the formation and membership of CoPs involving SDLs. The case study then goes on to consider the relationships between teachers and SDLs with a focus on the teachers' trust of the SDLs and the time that the SDL strategy had to develop. These factors are then shown to affect the potential for teachers to be influenced by the SDLs. This leads into considerations of any influence the SDLs seem to have on teachers' knowledge and practice. Through discussions in this case study, it is revealed how the introduction of SDLs challenges the CoP model and the examples used for explanation and clarification in Wenger (1998). Lastly, this case reveals some ambiguities in the TPACK context and delves into specific contextual elements that influence teachers' knowledge and practice when working with the SDLs especially in respect of CoP notions of alignment.

5.1. The ways in which a teacher's identity and participation are linked to the influence of SDLs on their knowledge and practice

This section will examine data which reveals the way different trajectories and imaginations influence teachers' participation in CoPs. Furthermore, interview and observation data will illustrate ways in which their participation, along with issues of trust and time, affect the formation and membership of CoPs when working with the SDLs. In exploring these issues, questions will be raised on the clarity of descriptions and definitions provided in Wenger (1998). Firstly, these questions will discuss the labelling of newcomers and old-timers. This will lead to answers which suggest there are more than just the two labelled groups and the way that individuals participate can be influenced more by their identity than whether they have just joined a CoP or have been there for a significant period of time. Secondly, questions will focus on the explanations and examples Wenger (1998)

used to expand on CoP theoretical elements. These will lead to suggestions that the concept of SDLs is difficult to explain through a CoP lens.

The identities of Paul and Roger defined through trajectory and imagination

Chapter 2 discussed the concept of identity and its importance in CoPs. In particular, the discussion highlighted that identity is "inseparable from issues of practice, community, and meaning" (Wenger, 1998, p. 145) and how "the formation of a community of practice is also the negotiation of identities" (p. 149), which have a temporal association with Wenger's conceptualisations of trajectory (pp. 153–156) and imagination (pp. 175–178). Through examination of the data, trajectory and imagination as part of a teacher's identity and how they influence how teachers position themselves for participating in a CoP will be revealed and explored.

Wenger (1998) argued that there are five types of trajectories. One of those, inbound trajectories, relates to identity being invested in "future participation, even though…present participation may be peripheral" (p. 154). In other words, there are individuals who see themselves very much on the periphery of a CoP at a particular time but they have the intention of fuller participation in the practice of the community. Paul's participation in the teaching team when working with the SDLs sees him very much in a peripheral position. He referred to wanting "to get to spend time getting to know the kids" (Paul, interview, 6 December 2017) and was observed to take on largely a behaviour management role when in the classroom. Paul's reasoning behind this peripheral participation related to the participation he foresaw in respect of having to teach the same students in other classes as they progressed through the school. Hence, through the data Paul provided, a focus on inbound trajectory will reveal how significant this was in shaping his identity. Further evidence will then show that having peripheral participation affected the formation and membership of CoPs when working with the SDLs.

When considering identity, there is a need to also look at how identity is formed, where "it is useful to consider three distinct modes of belonging" (Wenger, 1998, p. 173). These modes are engagement, imagination and alignment. The significance of imagination is in how "mutual engagement merely creates a shared reality in which to act and construct an identity. Imagination is another process for creating such a reality" (Wenger, 1998, p. 177). Roger provided several comments on how he saw the role of SDLs. These can be related to his identity as a teacher. Ultimately, he saw that the goal with SDLs was to move them "into a position where they are feeling like the teachers" (Roger, interview, 5 December 2017). Through the data, it will be revealed how his imagination, his perception of his role working with the SDLs and his current and future practice contributed to his identity with that goal in mind.

Paul's trajectory and Colin's imagination influenced their identities, how they participated in a teaching team, their involvement and the formation of a CoP built around the core concepts of mutual engagement, joint enterprise and shared repertoire. However, as discussed earlier, Wenger (1998) described trajectory as heavily influenced by past experiences, a person's history. For imagination, Wenger (1998) offered explanations to show that imagination is a social process: "the way nations use history to define a sense of common roots is a social process through and through, one that calls upon imagination to see the present as the continuation of a shared heritage" (p. 178). From this, we can also see how past experiences – social or individual – shape identity.

In research papers on educational CoPs, commentary on the experience of the data subjects and the level of that experience is common (e.g., see Fuller et al., 2005; Nistor & Fischer, 2012; Rogers, 2000). According to Nistor and Fischer, "participation is the way in which CoP members gain experience with the community of practice" (p. 3). Relating that to this research study, this case study will look at what experiences Paul and Roger gained as a teaching team working with the SDLs. However, what Paul and Roger previously experienced as teachers at the school or elsewhere will play a part in the formation of their

identities. Thus, a look at their relative experience coming into this research study is a good starting point. Hence, the following paragraphs will look at Paul and Roger's experiences through their demographic details through a CoP lens.

As mentioned at the outset of this case study, Paul was very much a newcomer to the school and had only fairly limited experience as a teacher, whereas Roger had plenty of experience in teaching – 35 years with 9 of those at the school. An overview of their demographic details can be seen below, taken from Table 3:

Table 6: *Paul and Roger's demographic details*

Name	Years teaching	Years teaching at the school	Qualified to teach in	Role in school	Experience in PBL	Involved in PBL planning	Joined PBL team
Paul	4	1	Science, Maths	Teacher	No	No	Semester 2
Roger	35	9	Chemistry, Physics, Maths	Teacher	No	Yes	At start of 2017

There can be little argument that Table 6 highlights a significant contrast in years of teaching between Paul and Roger. The table also shows that Roger had 8 more years at the school than Paul and he was involved in the planning for PBL, whereas Paul was not involved in the planning or the teaching until the start of Semester 2. Hence, this is a teaching team where one teacher, Roger, has more experience in teaching overall, more experience in teaching at the school and longer involvement in PBL, having been there from its inception at the start of the school year in which this research study occurred.

It is quite common in research to see discussions on trajectory involving either newcomers (e.g., Campbell et al., 2009) or old-timers (e.g., Green et al., 2013) or most commonly both of these (e.g., Floding & Swier, 2012; Woodgate-Jones, 2012). As in Wenger (1998), discussions where both newcomers and old-timers are involved usually position one person or group of people relative to others, such as where pre-service teachers are entering the teaching profession and working with experienced teachers or mentors or where an individual

is a trainee working with a claims processor with many years' experience. The focus in this case study is the teaching team of Paul and Roger and how they worked with the SDLs. Thus, the boundaries here are any CoPs that form as part of that teaching team and with the SDLs. However, given the demographic details in Table 6, it is difficult to position Paul as a newcomer and Roger as an old-timer in such CoPs, based on teaching PBL, if we consider that both had little experience with this approach prior to this research study.

Wenger (1998) really offered only the labels "newcomer" and "old-timer" to membership in CoPs. The only other labels, apart from actual job titles when using examples, seem to be generic "participant" or "member". Explanation of any membership between newcomer and old-timer is described in relative terms: "newcomers join a community of practice, generational discontinuities spread through multiple levels; relations shift in a cascading process. Relative newcomers become relative old-timers" (p. 90). This suggests a continuum of CoP membership, where labelling or defining who is a newcomer or an old-timer is based on participation between different members. Furthermore, with such a continuum, there is a suggestion that there are more than just newcomers and old-timers in certain CoPs.

The limitations in Wenger's (1998) descriptions of participation types creates difficulties in labelling Paul and Roger's CoP membership or potential membership as part of the teaching team. As already discussed, though, Roger had more experience than Paul as a teacher and in the school. What will become clear through the data is that Roger's experiences with the SDLs, his experience working at the school and his imagination contributed to how he participated in his team. Likewise, Paul's relative inexperience in teaching at the school and his trajectories made significant contributions to his contrasting participation. Thus, due to the ambiguities around definition of their memberships using the lens of Wenger (1998), the most significant factors to consider here are that, firstly, this was a teaching team comprised of one teacher (Roger), with considerably more experience in certain aspects of teaching than the other (Paul). Secondly, and of greater importance, each teacher participated entirely differently due to their identity factors. This means that the

teaching team provides an interesting angle for analysis of two teachers with many contrasts. The differences between how these teachers participated in the teaching team and with the SDLs are significant throughout this and the next section.

Paul and Roger agreed on the specific roles they would take in their teaching team, which shaped distinct forms of participation for each teacher. In observations, I witnessed Roger working specifically with a group of students and the SDLs in a class: "Roger seems to be focusing on students doing 3D design while Paul takes the rest of the class for this part of the lesson" (Researcher observations, 25 September 2017). Paul confirmed this in his reflective interview: "Roger had the group that were really interested in 3D design software" (Paul, interview, 6 December 2017). When asked whether that was his choice or Roger's, he talked about the joint decision that they had taken in respect of teaching PBL where, "I'll do a lot of the behaviour management" (Paul, interview, 6 December 2017) – a point that was confirmed by Roger in his interview. It can be deduced from the above comments that this was not a one-off situation that I observed. Instead, it was the way they had agreed to participate in the teaching team.

Paul's reasoning for more of a behaviour management role in the teaching team with Roger relates to his trajectory. It is how he saw himself working with these students in the future, and establishing himself in the school community will be influenced by his actions when first working with students in the school:

> With some of those kids I would almost rather have, be the one with them so I can build the relationships with them cos I'm gonna have them later on, so if we've got some sort of rapport already then it's saved me a little bit of time with planning and stuff and just wrapping my head round stuff as well. (Paul, interview, 6 December 2017)

The role that Paul described is not dissimilar to what Wenger (1998) described for newcomers on inbound trajectories: "their identities are invested in their future participation, even though their present participation may be peripheral" (p. 154). It is the sense that by taking on a specific role which, in some ways, limits his participation in the teaching team,

Paul was trying to establish relationships with students to assist his further participation as a teacher in the school.

However, Paul's comments do not relate only to trajectories. There are also correlations with how Wenger (1998) described the three elements of modes of belonging: engagement, "active involvement in mutual processes of negotiation of meaning" (p. 173); imagination: "creating images of the world and seeing connections through time" (p. 173); and alignment: "energy and activities…to contribute to broader enterprises" (p. 174). Firstly, Paul engaged with his team-teaching partner, negotiating participation. Secondly, he imagined that establishing relationships with students influences how effective he will become as a teacher in the school. Lastly, he does "what it takes to play his part" (Wenger, 1998, p. 179), aligning himself to a behaviour management role that both teachers agree is part of the practice of their team-teaching CoP. Modes of belonging stem from the need to "make sense of the formation of identity in a context" (Wenger, 1998, p. 173); thus, Paul can be seen to be taking the opportunity, given the circumstances of who he is working with and being relatively inexperienced in the school and to PBL, to "build the relationships" with students he recognises he will need for his proposed trajectories in the CoPs in the school.

Thus far, analysis of data on Paul has shown how his trajectory and factors relating to modes of belonging influenced his participation in the teaching team CoP. As was suggested earlier, his experience as a teacher in the school was also relevant in how it shaped his identity and ultimately his practice in this CoP. However, what is also evident in my observations and through Paul's comments in the reflective interviews, is that Roger had a very different role in the teaching team. Hence, the following paragraphs focus on his role, how he participated in the teaching team.

I asked Roger in the reflective interviews about his responses to the pre-involvement survey, particularly the score of 3 he gave himself for skill level in using digital technology (with 1 being the lowest and 5 being the highest). This can be seen in Table 4. As a leader in

the school, I had previously seen some of the high-quality work Roger had done with technology and believed this to be a relatively low self-assessment. Support for this view can be seen in Marg's comments on both Paul and Roger with reference to technology: "they have more skills and knowledge basically" (Marg, interview, 5 December 2017). Hence, I shared his surprise with the teacher about this. Roger's response was, "It's hard to measure yourself. What do you compare yourself against?" (Roger, interview, 5 December 2017). This indicates a certain sense of difficulty in providing an accurate score for his skill level. To get a more accurate representation of how Roger saw himself and how this shaped his identity, other responses in the reflective interviews can be examined.

In response to further interview questions, Roger talked about his approach and his views on using technology, which provide a better insight into how he saw his TK and his identity in this respect: "If I can have a go, if it's part of my teaching practice and I can have a go, and do stuff in terms of instructing kids in the best way then I'm getting better" (Roger, interview, 5 December 2017). This highlights his desire to learn; looking at this from a CoP perspective where "learning is the engine of practice, and practice is the history of that learning" (Wenger, 1998, p. 96), Roger is presenting how he sees the practice of the CoPs he is involved in. His views also relate to imagination as part of modes of belonging. They validate the belief that imagination "can make a big difference for our experience of identity and the potential for learning inherent in our activities" (Wenger, 1998, p. 176). Roger has created images of possibilities, images of himself in the sense that he sees that attempting to increase his TK (and possibly, related forms of TK, such as TCK and TPK) may lead him to become a better teacher.

As with skill level in using digital technology, from Table 4, Roger also gave himself a score of 3 for looking forward to working with the SDLs. His response to this in the reflective interviews was that he was expressing caution as he was "happy to be trained by students but there is always the work part, something else to it … so it depends" (Roger, interview, 5 December 2017). His cautious optimism, in this respect, forms an important foundation of

how Roger approached working with the SDLs and reveals his identity in terms of how he imagines what could happen when working with the SDLs. This will be built upon in the next section when we look at how Roger worked with the SDLs. At this juncture, the important point to state is that Roger, with previous experience of working with SDLs, is positive about working with the SDLs but recognises that such work can have issues. He is basing his judgement on past experiences, imagining what is likely to happen in participating with the SDLs. Despite the reservations he has and the "work part" issues he foresees in such participation, he is positioning himself to work with the SDLs.

Roger revealed more of his identity through his views on the results in Table 4; how there was a spread of rankings. He said, "Well, it's a lot of people involved. So, we're not all working to the same goals. We might think we are" (Roger, interview, 5 December 2017). This shows a certain sense of what Wenger (1998) described as "creating new images of the world" (p. 176), which he labelled as imagination. Furthermore, these comments highlight Roger's views on the alignment of teachers in the study. Roger recognised that there are variations in what teachers focus on, what is important to them – and in some ways what is expected of them – when working in the CoPs. However, his comment "we might think we are" also reveals that he believed the teachers were working towards the aims, the overall purpose: to deliver a PBL unit using 3D design and design thinking to Year 8 students with the SDLs involved in the process. From what Roger said about himself in trying to "get better" to "have a go", he recognised his own trajectory, the advancement of both his identity and practice as a teacher. However, at the same time he recognised that there were others who may not have bene on the same trajectory, or who perceived they were but in reality were not.

In order to consider the issues involved when teachers are "not all working to the same goals" a CoP lens can be used. Wenger (1998) talked about trajectories and learning as identity, saying that trajectories, "provide a context in which to determine what, among all the things that are potentially significant, actually becomes significant learning" (p. 155). In many ways, this statement supports Paul's approach to involvement in the teaching team,

focusing on behaviour management. This was “significant” to him at the time of the research study and to his inbound trajectory as a teacher in the school. Roger recognised that different teachers would have different approaches and different foci, depending on factors such as where they saw themself in the school, in respect of PBL, technology and working with the SDLs; and this, in turn, provided them with different “goals”. In other words, teachers have different identities and trajectories that shape their “goals”, which may affect how they participate in their teaching team CoPs.

Roger seemed quite sure of his “goals” in the way he talked about how “having a go” when it comes to teaching with technology will improve his teaching practice and how working with the SDLs could contribute to that. As stated earlier in this section, Roger was observed working closely with the students on 3D design. This was described by Paul quite succinctly: “a lot of the time he’ll lead the learning” (Paul, interview, 6 December 2017). With Paul participating in the teaching team in a largely, behaviour management role, Roger led the learning. Thus, how he participated in the teaching team with Paul seems to correlate with his identity, how he imagined himself as a better teacher, which then flows through into his participation in this CoP.

The preceding sections have explored Paul and Roger’s identities and how trajectories and imaginations influence how the teachers participated in the teaching team going into the research study and working with the SDLs. With a focus on trajectory and imagination as part of a teacher’s identity, examination of data has revealed that this was clearly a teaching team comprised of two teachers whose identities were very different. The data also revealed a clear understanding between the two teachers of negotiated roles in the teaching team. These roles correlate with what they revealed about their identities. The roles represented how they positioned themselves for participation in a CoP around their teaching team. In a behaviour management role, Paul’s participation was relatively peripheral, whereas Roger with more involvement, with both the students and the SDLs in teaching and learning with technology, was a more centripetal participant.

This section has served to establish the identity and participation of Paul and Roger in this case study. It has revealed how they participated in the teaching team CoP with Paul participating on the periphery and Roger being more centripetal. However, this section has only briefly considered the role of the SDLs. The next section will focus on how Paul and Roger's participation and issues they revealed in respect of trust and time affected the formation and membership of the CoPs involving the SDLs.

The formation and membership of CoPs with SDLs

Discussions in this section will centre on the CoPs involving both teachers – Paul and Roger – and the SDLs. It will continue with the premise that the teachers' participation was heavily influenced by identity. However, it will also consider other issues raised by Paul and Roger in respect of trust and time when trying to form CoPs with the SDLs. Teacher participation, trust and time will be shown to affect the relationships that the teachers form with the SDLs and how relationships affect CoP formation and membership. With all this in mind, the next paragraph will use a CoP lens to try to understand the significance of relationships in CoPs.

As described in the literature review, a CoP is reliant on three dimensions of practice, namely mutual engagement, joint enterprise and shared repertoire. Mutual engagement is where "people are engaged in actions whose meanings they negotiate with one another" (Wenger, 1998, p. 73), which is said to "create relationships among people" (p. 76). Hence, through membership in a CoP, and more specifically being mutually engaged with the shared practices of the community, members form relationships with each other. Wenger (1998) went on to explain how a shared practice, "connects participants to each other in ways that are diverse and complex. The resulting relations reflect the full complexity of doing things together" (p. 77). This highlights how difficult it is to precisely define how CoP relationships work, what specific factors contribute to forming relationships and sharing practice in a CoP. Thus, in this case study, there will be consideration of multiple factors: firstly, the

participation of teachers in the teaching team; secondly, issues of trusting the SDLs: thirdly, the time given over to the SDLs to work with the teachers and how that affected the forming of relationships between them. The relationships the teachers have with the SDLs will then be linked to the formation of CoPs with the SDLs involved.

As has already been established, Paul and Roger had agreed to quite contrasting roles in the teaching team. Seen through a CoP lens, Paul's behaviour management role positioned him on the periphery and Roger's role positioned him more centripetal in their teaching team. These positions and their relative forms of participation are reflected somewhat in the way that the teachers engaged with the SDLs. As discussed in detail in Section 3.1. (The context for this case study), the teachers were provided opportunities to work with the SDLs in a software training session, pedagogical discussion sessions and through in-class assistance. Figure 7 provides a timeline of key events involving the SDLs and the teachers; it shows that Roger was involved in the pedagogical discussion session, but Paul was not. This suggests that Roger had the potential to develop stronger relationships with the SDLs merely by consideration of his greater involvement with them. This involvement meant he was in a position to be engaged in the practice of developing pedagogical approaches to teaching with the technology with the SDLs, whereas Paul was not.

In the reflective interviews, I asked Paul specifically whether he believed the SDLs could become part of a teaching community or whether they were kept outside because they were students. His response was:

> For me, that would be my, probably the reason why I would be a bit sceptical about that because in the past when I've students involved with PD, generally they're a little bit timid and unsure and hard for them probably, to engage with … We're trying to learn off them. I'm very happy and very open to adjust my practice … but to get valuable information off them and for them to think deeply and be willing to share, I think that's the hard part. (Paul, interview, 6 December 2017)

These comments reveal further elements of Paul's identity, which seemed to influence the way he participated. He was clearly cautious about working with the SDLs. He revealed

issues with forming relationships with them. His use of the words “share” and “learn” as well as his reference to “my practice” correlate with how Wenger (1998, p. 76) saw “developing a shared practice depends on mutual engagement” in CoPs. Paul did not seem to trust the SDLs to “share” with him what he required or at the level he considered necessary to improve his practice. His mistrust did not seem to come from a lack of desire to learn from students and work with them to improve his practice; instead, from how hard he saw it is to get students to open up and “think deeply” and how he saw students not “willing to share”.

As Wenger (1998) talked about, experience in a CoP represents history of practice, which in turns affects an individual’s trajectory. Although Paul was a relative newcomer, he was a teacher for 4 years elsewhere before joining the school. It can only be assumed that what he experienced prior to coming to the school that working with “students involved with [professional development]” made him sceptical. In the reflective interview, Paul talked about how his experiences working students in roles such as SDLs led him to question “Is it productive? Do you actually get outcomes that you are after?” (Paul, interview, 6 December 2017). In essence, Paul does not seem to trust that an investment in his time with students will give him what he needs to advance his practice. This adds further evidence to understanding how Paul chose to participate in the teaching team. It seems that firstly, Paul participated on the periphery to focus on getting to know the students he would likely teach again as he develops as a teacher in the school. Secondly, past experiences that influenced him to mistrust the ability to form relationships with the SDLs which facilitate mutual engagement and really improve his practice are also key.

Shifting the spotlight on to Roger, issues of relationships and trusting students are a little more complex. Roger attended all three professional development sessions with the SDLs. He was observed engaging with SDLs in the pedagogy session, where he said, “my job was to say, to provide a bit of framework about what was happening and his job was to let him put things in and say, you know, test out the ideas” (Roger, interview, 5 December 2017). In this statement, Roger referred to the SDLs when he talked about “his job”. His comments provide

clarity on what he intended to get out of the pedagogy session, how he saw his role and his relationship with the SDLs. Lastly, he was observed working with students and the SDLs as they provided in-class assistance, "focusing on students doing 3D design" (Researcher observations, 25 September 2017). Hence, Roger not only had the potential to form relationships with the SDLs by being involved in all sessions but also he recognised ways that the SDLs could participate in developing pedagogy around teaching with technology and was engaged with them when they assisted in the classroom.

Despite the way Roger recognised the SDLs' roles, his position in the teaching team, which enabled him to participate fully in all sessions with the SDLs, and evidence of engaging with them, he still saw issues around working with the SDLs:

> So, I've always thought of, and that's the goal, but how you get there, across the board with students teaching you? And being a learning community in a classroom rather than being in a classroom? It's a big trick to pull off. (Roger, interview, 5 December 2017)

This comment seems to show that Roger had a certain level of understanding of how such CoPs involving students are hard to develop. It is perhaps surprising, though, to hear what Roger considered to be the reasons for the difficulties in creating a teacher-student "learning community". He talked about how "most of the resistance comes from the students. Cos I'm not resisting it. I'm looking for opportunities" (Roger, interview, 5 December 2017). In many ways, this aligns with Paul's earlier comments. Both seemed keen to learn from students and have them in roles where they can affect teaching practice. However, both felt that there was "resistance" from the students, although, unlike Paul, Roger did not offer what he believed were the reasons for the resistance. His comments merely offer evidence that there was something he had experienced before from participation in trying to form a teacher-student community with the SDLs.

The difference between Paul and Roger seems to be the way they reacted to their beliefs about difficulties in forming teacher-student communities with the SDLs. Paul did not seem willing to overcome the difficulties he described, whereas Roger did. Of course, it must be

recognised that the roles they took in the teaching team, how they participated, could determine their reactions. Paul may have been merely prioritising his inbound trajectory. In doing so, this takes him away from being in a position to address the issues he refers to when trying to work with students in roles such as the SDLs had. Paul, on the other hand, had a centripetal position which exposed him to work with the SDLs in developing approaches to teach with the technology being deployed. However, in respect of Roger, there is evidence that this is not the case. In the reflective interview, he went on to say how in trying to develop teacher-student communities, "it's identifying those points where you've got the connections with SDLs and then pick up and running with it … to keep trying to develop more competent SDLs" (Roger, interview, 5 December 2017). Here, Roger saw the worth in continued efforts to develop capacity in the SDLs to overcome what both he and Paul identified as issues when trying to learn from students in those roles. He was pinpointing specific elements that a teacher needs to recognise and respond to. In his comment "running with it", Roger seemed to be putting some of the responsibility on the teacher, and that by taking on such responsibility, this would lead to students who are "more competent". Competency, in this context, seems to relate to being able to participate as a CoP member around teaching at the level where Roger believed he could fully trust a student to be mutually engaged.

In the discussions thus far in this section, the focus has been on CoP formation and membership involving both teachers and the SDLs. Paul and Roger's identities and their participation as part of the teaching team have continued to contribute to the discussions. However, both teachers also shared views on how relationships with the SDLs were affected by trust and what this meant for forming CoPs with SDLs. Before moving on from the issue of trust, there are interesting, related perspectives offered by the principal. These, in some ways, correlate with what has been discussed in respect of teacher identities, teacher participation with the SDLs and how teachers engage with SDLs. The principal highlighted the relevance of previous experience described in Section 5.1. (The identities of Paul and Roger defined through trajectory) and in discussions on trust in this section. These comments

also begin to suggest that time is a factor that should also be considered.

In the wider context of all the teachers involved in teaching Year 8 students on this course, after the SDLs were introduced, the principal offered this view: “If you look at the PBL group of teachers this year I think some of those would probably be hesitant and not develop the capacity within the kids to take those steps, I think is one of the hurdles with SDLs” (Principal, interview, 11 December 2017). The principal was, effectively, looking at a group of teachers and making judgements on how she believed they would engage with the SDLs. Her judgements do not seem to be based on observations made, on specific data, although, of course, it is unknown what information or comments she was privy to while the teachers were involved in the research study. We can see that she is making judgements in the way she says “would probably” rather than stating what they actually “did”. In other words, without actually seeing them interact with the SDLs, without knowing what relationships they formed or did not form with them, she believed that there would be differences in how these teachers “develop the capacity” of those they work with.

The principal did not identify which groups of teachers were likely to be the ones who would be “hesitant” but she did talk about some teachers “that have got extensive experience to get behind the kids and letting the kids lead” (Principal, interview, 11 December 2017). Through this comment, she singled out aspects of identity that some teachers had developed and that others had not. These aspects of identity may have derived from competence within a CoP. Having experience “to get behind” relates to support, assisting development and improving students when they are involved in roles such as SDLs. In “letting the kids lead”, there are references to power and the empowerment of students. These were discussed at length in the Literature review (Chapter 2), where it was shown that SDLs is about students having active roles with some power, but some decision-making may be out of their control. As the principal, her comments were more likely to be based on factual information, what she knew of the staff employed in her school, their experience as teachers and, perhaps, their experience in other projects related to “letting the kids lead”.

Although the principal did not refer directly to trust in her comments, the way she talked about some teachers being "hesitant" and how that meant they would "not develop the capacity" of SDLs suggests this is a matter of teacher confidence. There are distinctions between trust and confidence, but they are related in some ways. Such a discussion is highly complex and beyond the scope of this research. The relevant point here is that "one's view of the trustworthiness of another person is likely to be influenced by many different kinds of discrete confidence judgements about that person's specific behaviours in a variety of contexts" Adams (2005, p. 11). Hence, among the PBL teachers, it was the principal's view that some would be making judgements about the SDLs and how they behave when working with the SDLs and, possibly, in other areas of school. This would influence the degree of hesitancy they had "to get behind the kids". Furthermore, she believed that greater experience in working with students in active roles alleviates that hesitancy.

The principal's focus on "experience" could also be linked to the factor of time, where certain teachers have had time to develop the necessary experience, but others have not. Factors of time and experience and some correlations between them can be seen in a range of CoP research: Participation is linked to development over time in Lave and Wenger (1991) and Wenger (1998); giving time to CoP members legitimatises participation (Wenger, 1999); a lack of professional experience affects identity and participation (Jawitz, 2009); a CoP sees members develop a shared repertoire of resources that include experiences. According to Wenger (2008), "this takes time" (p. 2). The principal seemed to suggest that the amount of time teachers have with the SDLs affects how much "capacity" they can develop and how much "experience" they can accumulate. In some ways, this draws attention to the length of time the SDLs worked with teachers in this research study. It prompts contemplation of whether changes to the length of time could affect the way teachers work with the SDLs, their experiences, relationships and trust. This will be considered for the remainder of the section largely through the views of Paul and Roger.

During the reflective interviews, Paul and Roger both offered insight into the notion that

length of time is a factor, and how that affected their capacity to develop relationships and trust with the SDLs. Paul talked about how some time for "planning before would definitely be very valuable" (Paul, interview, 6 December 2017), showing that he could see value in being given more time to work with the SDLs. When asked if working with the same SDLs again, on another project or in a similar project next year, would change how he interacted with them, Paul predicted that, "it would just bring the time it takes to form those relationships down a little bit. I could build up more trust in them" (Paul, interview, 6 December 2017). His views are clear in respect of how he saw that time is a factor, that the extent to which relationships can be built is dependent on time spent with the SDLs and that more time would enable the development of trust between him and the SDLs.

Roger's response when asked his views on whether teachers should be given more time to work with SDLs was far more perspicacious. He talked about how more time would enable him:

> To use the SDLs as the resource for kids who've done more and have had more experience with printing more off and know the whole system and mentoring with those kids. Then I can sit outside this and think, 'how can I use this in maths? How can I put this in so that I've got kids using it?' Cos I can see maths applications I haven't done anything with this year but I can see maths applications for it. (Roger, interview, 5 December 2017)

In the same way that Paul could see benefits to having more time with the SDLs, Roger was also positive about this. Roger's focus was on broadening the involvement to other areas of his practice and developing the way SDLs were used, though. He seemed to advocate for both a deepening of the SDL strategy with "mentoring" of students by the SDLs and for an expansion of the strategy that would see him being able to consider changes to his practice involving the SDLs. It is clear that Roger saw more time enabling such developments, but there is also a suggestion that relationships are involved. However, these are relationships between the students and the SDLs, rather than between a teacher and the SDLs, as Paul referred to.

When asked to expand on what he considers is the potential when continuing to work with the SDLs, Roger said, “So, we could have another level of sustainability where we could have with future developments. Cos we’ve done this entry level work with these students, cos we’ve developed these relationships, we can bring these students in somewhere else” (Roger, interview, 5 December 2017). This reveals how, through the time that Roger spent with the SDLs largely in the pedagogical session, he believed that he had formed relationships necessary at this “entry level”. The indication is that the “entry level” is a foundation that provides for developments, expansion and variants of the SDL strategy. This must be contrasted, however, with Paul’s views where more time would be needed to get to such a position.

Paul also referred to community when he talked about having more time with the SDLs, “in a community context, I think that’s probably a good way to describe it, and if we can bring them in to that community then it’s better” (Paul, interview, 6 December 2017). This shifts the focus somewhat in this discussion to how he recognised the significance of building a community and how that is a key component in relationship building, in establishing the trust of the SDLs. Although there was no explicit mention of community from Roger, both his comments regarding how SDLs could be used to “mentor” other students and “we can bring these students in somewhere else” (Roger, interview, 5 December 2017) suggest the development of community around teaching and learning.

Factors of trust and the time to establish trust have been discussed at various points within this case study. Their relevance when using a CoP lens has been highlighted in respect of the formation of and membership in CoPs. Likewise, there have been discussions on the significance of establishing relationships for mutual engagement to occur. As Paul suggested, if the strategy enabled teachers to “bring SDLs into that community”, he felt this would be beneficial. A factor in enabling this, or at least increasing the likelihood of its happening, is time. However, if we try to conceptualise what would happen should there be more time for teachers to form relationships with the SDLs, it is not clear from Paul’s comments, or indeed

from Roger's, at what point the SDLs could be considered members of a CoP with teachers. This leads into a discussion on competency of membership and participation in a CoP where participants need to work together for a long enough period of time to develop a sense of accountability and to develop a shared vision.

Wenger (1998) described that to be a competent participant in a CoP requires mutuality of engagement, accountability to the enterprise and negotiability of the repertoire, but 'this competence is experienced and manifested by members through their own engagement in practice" (p. 136). Breaking this down, mutuality of engagement is based on "the ability to establish relationships" (p. 137); accountability to the enterprise is "the ability to understand the enterprise of a community of practice deeply enough to take some responsibility for it" (p. 137); and negotiability of the repertoire "requires enough participation…in the history of a practice to recognize it in the elements of its repertoire" (p. 137). Thus, being a competent participant in a CoP and "engaging in practice" requires investment of time. Over a period of time, relationships can be formed to enable mutual engagement; understanding can be developed to gain accountability to the enterprise of the CoP; members can participate to a degree where they negotiate the repertoire.

Becoming a competent participant in a CoP is not something that can happen instantly. Time is significant. Through Wenger's (998) descriptions, links to what Paul and Roger describe in respect of developing trust and the significance of time given to working with the SDLs, can be seen. The SDLs seemed to be mutually engaged in trying to educate the teachers and students in 3D design but they lacked in both accountability and negotiability of repertoire, as Wenger described. Regarding repertoire, Wenger talked about how "this requires enough participation in the history of practice" (p. 137), and this links to what is seen in this case study with the SDLs. The suggestion is that limits on time given to working with the SDLs negatively affected the ability to develop a shared repertoire between the SDLs and the teachers.

Wenger (1998) stated that, “a community of practice acts as a locally negotiated regime of competence” (p. 137), which has the three dimensions already described: mutuality of engagement, accountability to the enterprise and negotiability of the repertoire. He described how learning must occur in all three dimensions regardless of a person’s position in a CoP. Advancing this explanation of practice, Wenger specified that “experience and competence are both constituents of learning but they do not determine each other” (p. 138). In the examples, Wenger provides for how, sometimes, competence drives experience and at other times the opposite can be seen. Descriptions in this case study do not make it easy to pinpoint exactly which of Wenger’s explanations of practice can be applied to the SDLs.

Looking at events from Roger’s perspective, the SDLs could be seen as newcomers to a CoP. However, with reference to newcomers, Wenger (1998) said that, “to achieve the competence defined by a community, they transform their experience until it fits within the regime” (p. 138). As already shown, there was not sufficient time, “enough participation in the history of the practice” (p. 137) for the SDLs to achieve competence in the teachers’ CoPs. Hence, the SDLs could be seen as newcomers who had not yet “transformed their experience”. From the data, it would be difficult to argue that they advanced beyond that position with the teachers. Any argument for the SDLs as newcomers in CoPs at the school and around this research study cannot focus on Roger and the SDLs in isolation, though. Looking at both Roger and Paul as a teaching team and a CoP they may have developed to work in the PBL program, Paul’s views immediately undermine the idea that the SDLs can be considered newcomers. He was clear on the need for more time with the SDLs than was offered in order to develop a CoP involving the SDLs and had issues of trust. Without being able to develop these due to the confines of the research study, the membership of SDLs in any CoPs involving teachers is uncertain.

Wenger (1998) provided examples that considered an alternative description where experience drives competence. If this description is applied to the SDLs working with teachers, the suggestion is that involving the SDLs is an “attempt to change the community’s

regime so that it includes their experience" (p. 138). In other words, we would see evidence of their experiences as students, learning and using the technology, driving the competence of teachers in the CoPs they worked with. However, such changes to a regime suggest a long-term, sustained change in practice. This would likely be more than the PBL classes observed. Hence, to fully establish whether this occurs, there would need to be analysis of the SDLs working with teachers for a longer period of time, which is beyond the scope of this research study. This provides further evidence of the impacts that limitations of time have on a SDL strategy.

The last few paragraphs have looked, primarily, at issues of trust and time through a CoP lens. They have provided important points to consider in respect of developing a sense of accountability, developing a shared vision and how competency and experience relate to the ability to participate in a CoP. To summarise, many of the points raised can be applied to how this SDL strategy enabled or hindered teachers and SDLs working together in this case study and how, ultimately, that would affect any influence on teachers' knowledge and practice. However, despite all these discussions, conflicting conclusions remain. The examples and descriptions provided in Wenger (1998) for establishing a regime of competence do not facilitate being able to construct a unified, accurate description of any affects that the length of time working with the SDLs had on the teachers involved. That is to say, conclusively, if more time to work with the SDLs were given to the teachers, this would result in the SDLs having competent membership. What is clear, however, is that both Paul and Roger recognised that there was potential for greater pedagogical influence in working longer with the SDLs and establishing stronger relationships, and that this could be facilitated by having more time.

The idea that there is potential for SDLs to influence teachers needs to be further analysed in respect of what actually happened to Paul and Roger's knowledge and practice. Without doing so, the research question is not fully answered. In other words, this research study is not about what could happen. It is about what *does* happen; how the introduction of student

digital leaders *does* influence teachers' knowledge and practice. Hence, the next section will focus on these points.

How SDLs influenced Paul and Roger's knowledge and practice

Having discussed the complexities in deciphering the formation and membership of CoPs involving the SDLs and the teachers thus far, it has been established that there was potential for the SDLs to influence Paul and Roger. Influence on a teacher's knowledge and practice requires not only the further use of a CoP lens but also the introduction of TPACK. This section considers issues already discussed in respect of trajectories, imagination and participation but considers evidence of what actually happens when the SDLs work with teachers. It looks at the influences the SDLs have on teachers and considers how that happens.

Before commencing exploring data on how the SDLs influence teachers, the teachers' involvement in the three stages of this research study is a worthwhile reminder of potential influence. As highlighted previously, Paul focused on behaviour management with Roger expected to "lead the learning" (Paul, interview, 6 December 2017). This resulted in Paul not attending the pedagogical session. When asked why he was not involved, Paul confirmed that he felt that, "it was really more helpful for Roger to decide on those things … I had other commitments" (Paul, interview, 6 December 2017). Using both a CoP and a TPACK lens here, it could be argued, that just by this very decision, by Paul prioritising a role that relates to his trajectory and identity as a newcomer, he was potentially affecting developments in his TPK.

Paul was present at the software training session. Hel reflected on what he felt he had gained in terms of TK from that session:

> I think once I finally started and they gave a couple of pointers, I kind of felt like I didn't need the instructions anymore and I wanted to go away and do it myself, erm … I don't know if that's kind of an attitude I have, I don't know maybe it's something I do. For me, it's how I enjoy learning. (Paul, interview, 6 December 2017)

His comments show that he sees himself as a learner, how his trajectory "has a coherence through time that connects the past" (Wenger, 1998, p. 154), which Paul connected with his situation. Although he expressed uncertainty as regards to its being "an attitude I have" or "something I do", Paul was clearly recalling an approach to learning that was not new to him. In other words, he had previously used a somewhat independent approach to learning, which he deployed again to "enjoy learning" during the session. He was, in essence, relating to how he had learned in similar situations in the past and expressed his desire to continue to learn that way, to follow the same trajectory in this respect.

As to how much Paul's negotiated peripheral position in this teaching team affected his willingness or desire to listen to instructions of the SDLs is unknown. It is possible that he could have decided, perhaps subconsciously, what he considered he would likely need to know, given how he intended to participate. This would then correlate with the notion that that SDLs had only limited influence on the teachers on the periphery of CoPs. However, Paul offered greater insight later in the reflective interview when he said, "I would say I'm pretty digitally literate already, erm, I'm pretty happy to go and play with things and see how it goes" (Paul, interview, 6 December 2017), which supports his self-reported views on being confident and skilled at quite a high level, as detailed in Table 4. My observations of the software training session reinforce Paul's views on his technology skills and confidence. In this, I noted that he did not ask for any help and "the 1st to complete the first 2 tasks" (Researcher observations, 20 September 2017). Hence, it is more likely that what can be seen here are limitations to the influence the SDLs can have on teachers with high skill levels and confidence in using technology. This may also hint at similar limitations for the SDLs' influence when teachers have highly developed TPACK, which can be judged through Roger.

In Table 4, it can be seen that Roger self-reported at the same level for confidence in using digital technology but only slightly lower in terms of skill level when compared to Paul, the validity of which has already been discussed in Section 5.1. The similarities in how these teachers saw themselves in respect of confidence and skills in using technology offers the

opportunity for some comparisons to be made between how the SDLs influenced Roger and what was seen to be the influence on Paul. As the previous paragraphs have focused on Paul's responses to his experiences in the software training session, it seems sensible to start at the same place with Roger.

Roger's reflection on the software training session were "It helped me learn about this software which I might not have done cos it's the time factor so having an impetus for me to go and actually … you know … do it" (Roger, interview, 5 December 2017). In similar ways to how Paul reveals some elements of his identity in his comments about how he saw himself as a learner, Roger did likewise. He suggested a need to be encouraged to get started, to find time to focus on the learning and be able to gain TK. However, both Roger's comments and those of Paul in respect of the software training session reveal little of the value of the SDLs' input. In other words, they seemed to be talking about what they had gained from the session rather than from those leading the training, and it could be argued that a different trainer, a teacher or an outside expert could have provided a similar experience. That is to say, Paul and Roger could have given the same responses as those featured here; they might have developed their TK to the same degree regardless of the trainer. The same cannot be said, however, when Roger reflected on the pedagogical discussion session which he chose to attend and Paul did not. This is where we can see more evidence of wider TPACK development rather than just TK and how the SDLs directly influenced that development. These will be featured in the following paragraphs.

During the pedagogical session, I made the following observation notes:

> Roger asking SDLs views on how to teach with software. Says 'would it work well if….?' Which was about grouping and class dynamics and then there was a further discussion about approaches, asking SDLs advice. Sounded like the sort of discussion a teacher would have with another teacher. (Researcher observations, 1 November 2017)

This observation portrays the way that Roger seemed to be approaching the session, wanting the SDLs to give him information, their opinions, their views on certain aspects

related to the teaching and learning with that particular technology. A later observation note said, “SDL treated like a peer in discussion with Roger” (Researcher observations, 1 November 2017). When asked his thoughts on these observations in the reflective interview, Roger replied, “It took a while for [SDL name 1] to realise that I was actually, you know, looking at equals, but then when he fit into that it was fine” (Roger, interview, 5 December 2017). This highlights how Roger approached the session, saw the SDLs’ role and, in some way, had expectations of what they could provide him not as a student but as an “equal”. The equality was in respect of having learned and considered how best to teach with the technology.

Looking at Roger’s approach to the SDLs in this session from a CoP perspective, Roger imagined their role and what they could provide. He engaged in working with the SDLs to enhance his knowledge. Both of these elements of modes of belonging enabled him to “create a shared reality in which to act and construct an identity” (Wenger, 1998, p. 177), and that identity is as a learner, somebody who is looking to enhance his practice by working with the SDLs. However, given that Roger had previously worked with SDLs and negotiated a centripetal position which he saw as important to how he wanted to improve himself as a teacher, this could also relate to previous experience, his identity and trajectory. He might have been expecting certain insights from the SDLs, such as knowing if an approach “would work well if …” because this was the sort of information students had shown him they could provide. On this matter, Roger talked more holistically about how he saw students’ knowledge and the potential to use that to his advantage: “I’ve often had students who’ve known how to do things in class and I’m like, ‘ok’, especially to do with technology because that goes in so many directions” (Roger, interview, 5 December 2017). Thus, it seems that Roger’s approach to teaching, his identity as a teacher, enabled him to proactively engage with the SDLs and transfer the positive experiences he had in the classroom to a session that was primarily about planning to teach.

Focusing on these elements of Roger’s identity when working with the SDLs in the

pedagogy session is following what Wenger (1998) described as "our ability…to shape the meanings that define our communities and our forms of belonging" (p. 145). Roger has invested in this process, and in doing so was defining a community that had him as a learner, a recipient of information, of advice, of guidance on how to improve his teaching with the 3D design software. Accordingly, it can be concluded that Roger was creating an ideal environment to have his knowledge positively influenced by the SDLs. Using a TPACK lens, we can see that Roger is setting up a situation where his TPK and maybe even his PK can be influenced, in addition to what he had gained in respect of TK in the software training session.

As to whether the potential for influence was realised as actual influence for Roger, his replies from the reflective interviews are important. He was asked to consider whether working with the SDLs had any influence on him, to which he answered:

> Erm … Not influenced them in the way I would run things. And that's not to say they have done a bad job or anything, that's just there are things I would do differently, I would structure things differently, I would, you know, I do have more knowledge than them so err, but the bit when they were showing, 'this is what I learned and this is our failures we came up with' which would sound more artificial coming from me. Though at this point in time their approach wouldn't work coming from me, I don't think anyway, whereas it's a good approach, it's a good way for the kids to learn. So, if I was getting some kids to do some teaching of some other kids in classes, 'tell them about this', I would emphasise things go wrong. (Roger, interview, 5 December 2017)

From his comments, Roger seems to be initially describing ways in which the SDLs had not influence him. However, the key aspect in the first part of Roger's reply seems to hinge on interpretation of how he "runs things", which he also related to "structure". These could be linked to how Roger considered the way he organised his teaching, how he approached teaching a particular class. Given the involvement of technology, this could also relate to how he structured his teaching when integrating technology or at least when introducing new technology. Furthermore, there is the possibility that he was referring to how he approached teaching when working in a team, often with larger class sizes, working in a PBL

environment and with only some students using 3D design. When Roger talked about having "more knowledge than them", the evidence that is more likely to be about the organising the teaching of the class comes from the fact that he had already acknowledged in early comments about students being able to offer him knowledge of the technology and in the remainder of the quote above that he valued their input on strategies to teach with technology.

These comments from Roger that he was not influenced by the SDLs seem to contradict, to some extent, what he said in observations already provided: "Roger asking SDLs views on how to teach with software…about grouping and class dynamics and then there was further discussion about approaches, asking SDLs advice" (Researcher observations, 1 November 2017). It also seems to go against statements he made in the reflective interviews when he talked about seeing SDLs as "equals". Lastly, his comments need to be counterbalanced with observations made in the pedagogy session, when the SDLs worked in in-class assistance sessions and in Roger's reflections. In the pedagogy session, "[SDL name] suggests a number of SDLs that should be in to work with the class, saying, 'oh you are gonna need 2 or 3'" (Researcher observations, 1 November 2017). When I observed the class, there were three SDLs provided for the in-class assistance sessions. I asked Roger later in the interview, "How much did you follow through with what [SDL name] advised?", to which he replied, "I think we more or less followed through with that idea" (Roger, interview, 5 December 2017), highlighting how he and Paul implemented the SDLs' suggestions when teaching students.

Roger talked later in the reflective interview about different strategies he used with the two groups he and Paul worked with, one of which was sent from Faith's and Marg's class. He said that he "targeted the kids" (Roger, interview, 5 December 2017) more with the second group, adding "that's what we started to do, target the things that they will need, and err, the other group will have the experiential" (Roger, interview, 5 December 2017). This idea of targeting individuals or targeting different approaches with different students was not something that was observed being discussed with the SDLs in the pedagogy session. Thus, it can be assumed that Roger's negativity in respect of the SDLs influencing him in relation to

“running things” and “structuring things” was in respect of the targeting approaches he had decided to use.

The remainder of Roger’s reply as to whether working with the SDLs had any influence on him is far more positive. He recognised the approach that the SDLs had taken in sharing their learning with the software and the struggles they had; how this was a valuable approach to be used with students but it “would sound artificial” coming from him. Using a CoP lens, Roger appeared to be using his imagination and possibly some historical trajectory as he believed how students should be learning and could see such an approach would support that. He had already recognised the SDLs’ knowledge of technology and what students with such knowledge could offer to the way he wanted to approach his teaching practice.

The manifestation of the SDLs’ influence on Paul and Roger’s knowledge, in other words, how the SDLs influenced not only the teacher’s knowledge but also their practice was witnessed in researcher observations. The SDLs worked directly with students during Paul and Roger’s in-class assistance sessions. They delivered to the whole class, “SDLs intro software to whole class from whiteboard at the front” (Researcher observations, 7 November 2017) at the start of the lesson. They worked with groups of students, assisting them in learning how to use the software. What they did was clearly influencing practice as without their involvement, the teachers, or at least one of the teachers, would have had to work differently than they did. They would have had to take on some of the responsibilities in ensuring the students knew how to use the software. Lastly, as has already been discussed, Roger put into practice advice from the SDLs about how many would be needed, given his class size. This in itself is proof of some degree of the influence of the SDLs on his practice.

Thus, to sum up these discussions on whether the potential for influence was realised as actual influence for Roger, it would seem that TPK was influenced by the SDLs but only in certain respects. Roger had beliefs about how the SDLs could influence his knowledge, how they could be useful and what their role could be when working alongside him in class. He

had then developed some elements of TPK to add to TK he had gained earlier from the SDLs around teaching with the technology. However, Roger had also clearly made decisions as to where he saw their influence and where he felt he had superior knowledge and experience that prevented him from taking on their advice. The influence of the SDLs was not only on knowledge but also on practice for Paul and Roger's teaching team, with the SDLs playing an important role providing in-class assistance to their teaching with technology.

This section has looked at how Paul and Roger were influenced by the SDLs in respect of knowledge and practice when teaching with technology. It has been shown that Roger was influenced to a greater degree, and Paul less so. There is clear evidence of Paul in a peripheral position and Roger in a more centripetal position, both having their TK influenced to some degree when in the software training session. The connection between having the SDLs as trainers and the degree of influence on teachers' TK is not clear. In the pedagogy session, with only Roger from this teaching team involved, influence on his TPK could be clearly seen in areas that supported his beliefs about students' knowledge and the specific roles that they could play in helping him integrate technology. The majority of these areas relate to SDLs passing on knowledge to the students in his class on how to use the technology and assisting them in developing their skills. However, there are some specific areas where Roger developed knowledge on organising the class from the advice of the SDLs. Lastly, it has been shown that the SDLs' influence was not just on knowledge. It also advanced into practice that affected both Roger and Paul in the classroom.

From this case study, thus far, we can summarise a number of points: Firstly, membership in a CoP cannot always be given definitive labels such as newcomer or old-timer. A number of factors contribute to identity and participation. What is of far greater relevance when using a CoP lens is an understanding of an individual's identity and how they participate in the CoP. Secondly, identity and participation in a team-teaching CoP affect the formation and membership of CoPs involving SDLs. Thirdly, the potential for greater influence from the SDLs on teachers' knowledge and practice has close links to the level of trust, the strength of

the relationships between the teachers and the SDLs as well as the time a SDL strategy has to develop. Trust, relationships and time contribute to mutual engagement in a CoP. Fourthly, teachers with a more centripetal participation in a teaching team CoP are more likely to have their TPACK influenced to a greater extent by SDLs than those on the periphery. Lastly, practice can be influenced even for those teachers with peripheral participation in a teaching team CoP where SDLs provide in-class assistance. SDLs' involvement in the classroom affects the practice of both teachers as the SDLs take on roles that teachers may have had to provide themselves if the SDLs were not involved.

5.2. SDL roles challenge the CoP model

The previous section showed how the SDLs influenced Paul and Roger's knowledge and practice. The summary provided at the end of that section gave an overview of the key points. The intention throughout Section 5.1 was to show how a teacher's identity and participation are linked to the influence the SDLs have on teachers' knowledge and practice. In other words, the key points are related. There is a sense of how the revelations in Section 5.1. evolved to where Paul and Roger's knowledge and practice are shown to be influenced by the SDLs. Throughout all those sections, the CoP lens from Wenger (1998) was used. Identity and participation in CoPs, formation and membership of CoPs have all been prominent issues in being able to develop the narrative around the teaching team and how they worked with the SDLs. At various points in those sections, in the use of the CoP lens, questions have been raised on how Wenger's descriptions and definitions can be applied. This was seen early on when Paul and Roger did not seem to fit with the labels of newcomer and old-timer. However, there are also issues that continually appear throughout Section 5.1 (particularly in The formation and membership of CoPs with SDLs), which suggest difficulties in trying to understand the SDLs by what is featured in Wenger (1998).

This section will focus on the idea that SDLs challenge elements of the CoP model that Wenger (1998) described. It will argue that there is something abstract about teachers

working with SDLs and the roles that SDLs are seen to play through this case study. Discussions will return to the components that made up Section 5.1: identity, participation, formation and membership of CoPs. They will look critically at descriptions Wenger provided and the examples he used to illustrate CoP theories and models. By doing this, it will be shown how problematic it is to try to apply some of these in the context of this research study.

Section 5.2 advanced discussions that featured just the teaching team of Paul and Roger to looking at the formation and membership of CoPs involving the SDLs. It was clear from the evidence presented that Roger was beginning to form a CoP with the SDLs but Paul was not. Thus, we have a situation where the focus is on concepts of membership and non-membership of CoPs as described by Wenger (1998). These prompt considerations of marginality and peripherality, which will feature in forthcoming discussions. All of these concepts have their foundation in identity and participation, which will be explained as a lead into the focus elements.

Identity is said to be:

> A layering of events of participation and reification by which our experience and its social interpretation inform each other. As we encounter our effects on the world and develop our relations with others, these layers build upon each other to produce our identity as a very complex interweaving of participative experience and reificative projections. Bring the two together through the negotiation of meaning, we construct who we are. In the same way that meaning exists in its negotiation, identity exists – not as an object in and of itself – but in the constant work of negotiating the self. It is in this cascading interplay of participation and reification that our experience of life becomes one of identity, and indeed of human existence and consciousness. (Wenger, 1998, p. 151)

This description removes the notion of identity being merely about how an individual sees themselves or, just as important in this context, how they are seen by others. Instead, the concept of identity is far more complex; perhaps, one could say, more sophisticated. According to Wenger, identity constantly evolves out of experiences people have when

participating and the way these experiences manifest into actions through being reified.

The "complex interweaving of participative experience and reificative projections" (Wenger, 1998, p. 151) that make up identity explained above manifests within a CoP as "the way members engage in action with one another and relate to another" (p. 149). Being a full member of a CoP leads the dimensions of competence – mutuality of engagement, accountability to an enterprise, negotiability of a repertoire – discussed in the previous section, to becoming dimensions of identity (Wenger, 1998). There is, however, the antipodal situation, where non-membership in a CoP means "we do not quite know how to engage with others. We do not understand the subtleties of the enterprise as the community has defined it. We lack the shared references that participants use" (Wenger, 1998, p. 153).

As already discussed in Section 5.1. (The identities of Paul and Roger defined through trajectory), in CoPs, the significance of the old-timer and newcomer membership is continually referenced to explain contrasts in identities, in practice and in roles (Wenger, 1998). It was argued in that section that neither terms were suitable explanations for Paul and Roger. However, an analysis of Roger's relationship with the SDLs seems, in some ways, to portray the beginnings of a CoP or at least the potential for a teacher-student CoP, as already discussed. In such a CoP, SDLs could participate as newcomers if there were a longer time given for them to develop relationships with the teachers. Thus, we have a situation where the evidence in this case study shows that the SDLs remained outside of their CoPs during this research study, meaning they had non-membership. However, both teachers recognised the potential for the SDLs to have membership. Understanding CoP membership and non-membership relies on grasping the concepts of marginality and peripherality (Wenger, 1998).

Marginality involves issues of participation and non-participation (Wenger, 1998). Wenger recognised that, "because we inevitably come in contact with communities of practice to which we do not belong, non-participation is an inevitable part of living in a landscape of practices" (p. 165). However, he then went on to focus on the interactions

between participation and non-participation, how different relations between them can be used to explain the differences between marginality and peripherality. Those communities to which people are exposed to, but do not belong to, were not discussed further by Wenger.

Peripherality is central to "the process by which newcomers become included in a community of practice" (Wenger, 1998, p. 100). Although Wenger then proceeded to say it "provides an approximation of full participation that gives exposure to actual practice" (p. 100), which would seem useful in terms of analysing the role of the SDLs, the discussions quickly went on to refer to newcomers on an inbound trajectory. In other words, the relevance of peripherality seems to be in the context of those newcomers in a CoP and how they gain legitimacy in and access to a CoP.

Marginality and peripherality both offer very small explanations for what was experienced by the SDLs, but they are far from insightful when used to try to understand the roles and relationships that the SDLs had when working with Paul and Roger. It is understandable, in some ways, given that Wenger's (1998) book is about CoPs, it will inevitably detail roles within these communities, but perhaps Wenger was being too simplistic in depicting such roles. Conceivably, there are other roles or situations where the conditions of a CoP and the requirements for membership are not the same as those Wenger described. There seems to be evidence in the data and the discussions in Section 5.1 to suggest this, and an explanation about this is required.

The description of claims processing and the roles that members undertake in the CoPs in that example offer what is, arguably, a typical business organisation. It was chosen by Wenger for the study as "it is a collective construction of local practice that, among other things, make it possible to meet the demands of the institution" (Wenger, 1998, p. 46) This, in itself, does not appear to be very different from how a school would operate. It is only when we start to examine the roles within claims processing that Wenger used to explain developments of CoPs, identity and practice, that there seem to be differences. These create a

void in understanding the role of the SDLs and how they can fit it into a CoP model.

Wenger (1998) described a CoP through the example of claims processors as a community where there is turnover of staff that form a "system of interrelated forms of participation where relative newcomers become relative old-timers" (p. 90). The descriptions of how the CoP develops and redevelops and how membership changes and "relations shift in a cascading process" (p. 90) depicts a community that has predefined roles through which people ascend in the organisation as they develop from newcomers through to old-timers. It seems somewhat of a linear structure and clearly one based on progression and job promotion. This seems at odds with the way the SDLs were set up to operate in this research study. The SDLs were not intended to be in roles where they were looking to become teachers. Obviously, the school in the research study and, indeed, some of the CoPs that the teachers are in may have similar traits to what Wenger described for claims processing. Teachers may have similar trajectories, and opportunities may exist for newcomers to become old-timers. However, when the focal point is the involvement of the SDLs, any CoP that could develop between teachers and students is unlikely to have the same role developments or structure based on progression, job promotion or trajectories.

The SDLs essentially work with teachers on a temporary basis. Admittedly, with enhancements to the approach used addressing time and trust issues for the teachers, the SDLs' roles could be less temporal. However, it would be hard to see a situation where SDLs have inbound trajectories to becoming teachers; or, alternatively, if they become more centripetal in a SDL role, what effects that would have on teachers. Any teacher-student CoP where SDLs are "joining the community with the prospect of becoming full participants" (Wenger, 1998, p. 154) could mean the development of roles as a SDL. In other words, with greater development of the SDL concept and how it is organised, one could predict turnover, with relative newcomer SDLs becoming relative old-timer SDLs. SDLs working with teachers is very different to claims processing, though. SDLs are students whose trajectories are entrenched in that role. Their reason for being at school is likely to be to learn, to achieve

qualifications. It is unlikely to be for the purpose of what being a SDL offers. Teachers, in contrast, are the people employed to educate these students. In other words, the fundamental aspects of both students and teachers' identities and how they position themselves to participate are likely to be very different. It could even be said that teachers and students are unlikely to have more than temporary mutual engagement, joint enterprise and shared repertoire by virtue of their contrasting identities and participation within a school's CoPs.

Analysis of some of Roger's comments provides some interesting angles to add to what has been discussed thus far in this section. As has previously been described, Roger aspired to have students teaching others in his class and have students as facilitators when integrating technology. He described specific situations with the SDLs when he was "looking at equals" (Roger, interview, 5 December 2017). Reflecting on his practice, Roger said that he has "used kids as 'go-to' people in classrooms, particularly around digital stuff" (Roger, interview, 5 December 2017). This seems to support his belief in trying to raise the aspirations of students and, in some ways, elevate their roles from just being learners. However, his use of the word "used" in this context suggests there remains a divide, perhaps subconsciously, between how he saw a teacher and how he saw a student or a SDL. One has to question whether Roger would say he "used" a teacher who was team-teaching with him or assisting him. Furthermore, this highlights how distinctive SDLs are from any of the roles that Wenger (1998) described. The terms Roger used do not seem to fit with those used in claims processing.

Roger went on talk about how with SDLs, there are "some conversations I wouldn't have, some stuff I wouldn't talk about" (Roger, interview, 5 December 2017). Arguably, this is not dissimilar to what Wenger (1998) described for different roles, histories of practice and boundaries in claims processing. However, Roger's description has its foundations in the roles that students take within the school and could stem from professional responsibilities, confidentiality, expected norms and the roles that exist in a school. It highlights barriers to entry for SDLs into CoPs with teachers, which would be difficult to overcome. This is also

not something that aligns with how Wenger (1998) described development from newcomer to old-timer, from peripheral to centripetal participation.

Paul's views offer a different dimension to this discussion. He talked about the value of "getting the insight from the people that are typically your customers" (Paul, interview, 6 December 2017). Although it has already been discussed in previous sections how Paul's relationship with the SDLs did not really have much chance to develop due to the role he took on in the teaching team, this positions the SDLs in a role that is completely abstract to anything described in Wenger (1998). If taken literally, perhaps SDLs working with teachers could be aligned to claims processing if customers of the organisation were put into roles where they worked with members of that organisation. Wenger does not describe such a situation.

As there are clearly difficulties in aligning the way Wenger (1998) talked about those participating in claims processing CoPs and the teacher and the SDLs in this research study, other areas of CoP theory may be relevant. The SDLs could be seen to have boundary trajectories. This would mean that they are "spanning boundaries and linking communities of practice" (Wenger, 1998, p. 154). With such trajectories, they would be in brokering roles. This could explain how they link student CoPs with teacher CoPs. However, the issue is that brokers have, according to Wenger, multi-membership to the CoPs they work with. However, it has already been shown that there are issues with the formation of CoPs that involved the SDLs and the teachers in this teaching team. Thus, it is difficult to see the SDLs as having multi-membership in respect of working with Paul and Roger. However, further discussions relating to boundary trajectories and the SDLs as brokers will appear in the case study on Tom and Emma.

In summary, what we have seen in this section is how the SDLs are in very different roles from any that Wenger (1998) described in claims processing. Regardless of how the SDL strategy develops, they will remain students of the school, which in itself affects their

identity, their role, the potential for their role and relationship development with the teachers. It also creates a situation that is difficult to explain from what is described by Wenger. The introduction of SDLs working with teachers challenges the CoP model as the degree to which the SDLs can influence teachers' knowledge and practice requires some understanding of the identity of students in SDL roles. It can be seen in this case study that the SDLs are not newcomers to a CoP with teachers as they do not gain membership. The SDLs could be said to have peripheral trajectories where "some trajectories never lead to full participation" (Wenger, 1998, p. 154). However, as Wenger did not expand on this concept in any great detail, it is difficult to see what effect this has on their identity and thus apply this to what has been seen in this research study. Hence, there remains a situation where the SDLs challenge the CoP model described by Wenger.

5.3. Conclusion to Case study 1

This case study described Paul and Roger working as a teaching team and their involvement in the three stages working with the SDLs. It focused on their relationships with each other and the SDLs, trying to understand how their knowledge and practice was influenced by working with the SDLs. Discussion and analysis in this case have resulted in three main conclusions:

1. **The roles that the teachers take in a teaching team and their positions in CoPs can determine the degree of influence that SDLs have on their knowledge and practice.**

Analysis of Paul's comments in the reflective interviews and observations of lessons highlights how he had little interaction with the SDLs when they provided in-class assistance. By focusing on trajectory, Paul clearly valued a role that took him away from integrating technology in his practice and working with the SDLs. He was aware of his relative inexperience in the school and the need to build relationships with the students in the PBL class to facilitate an inbound trajectory as a teacher in the CoPs in the school. Thus, when the

SDLs were involved with this PBL team, Paul took a peripheral position rather than be more centripetal to the practices in the CoP.

A similar analysis of Roger and the comments he made about himself and the SDLs reveals the significance of imagination in determining how teachers work with the SDLs. Imagining what is possible or, conversely, limiting one's imagination to focus on problems when working with SDLs ultimately affects the roles that a teacher takes when working with the SDLs. In turn, this alters the degree of influence the SDLs can have on a teacher's knowledge and practice.

These findings have implications for understanding how the introduction of SDLs can influence a teacher's knowledge and practice when they are working in a teaching team. Being part of a teaching team enables teachers to take quite specialist roles, which influences the position they take in a community. These roles may be focused on particular areas, which has them working with technology or working on other elements of their practice where technology integration is of little concern. Their roles determine the amount of influence the SDLs can have on their knowledge and particularly their practice. Teachers can have their TK or even their TPK enhanced by the software training and pedagogical discussions sessions with the SDLs. Enhancement in practice needs to come, however, through attempting to integrate technology into practice when teaching. If a teacher is not in a role in a teaching team where they are involved with teaching students how to use technology, in other words, not centripetal to the practices of the CoP, this practice will not develop.

This may have wider implications for targeting aspects of a SDL strategy on specific teachers in a teaching team, so that there is a focus on those who are likely to value the influence of the SDLs and enhance their practice accordingly, by inviting certain teachers in a teaching team to certain sessions or identifying which of the teachers will work with the SDLs during in-class assistance. An alternative way to introducing SDLs to work with teaching teams could be to single out one teacher from each teaching team to work with the

SDLs. That teacher then undertakes training, builds relationships with the SDLs and is responsible for liaising with them during in-class assistance. This could enhance the impact of the SDLs on that teacher, which may lead to greater influence on that teacher's knowledge and practice. However, it would also mean that fewer teachers have the potential to be influenced by the SDLs. In other words, there is a variety of approaches that can be taken to maximise the effectiveness of working with the SDLs. Consideration of the teachers who participate and devise a strategy so that they are influenced as intended could be a worthwhile exercise before introducing the SDLs.

2. **The relationships teachers develop with SDLs are significant in determining the degree to which the SDLs can influence teachers' knowledge and practice. Having more time with the SDLs can encourage these relationships to develop. This potentially affects the length of time that a SDL strategy is scheduled to run for.**

In this case study, both teachers expressed a desire to learn from the SDLs and were open to having their knowledge and practice affected by working with them. However, the teachers decided on specific roles that they would take in the teaching team, and this limited Paul's exposure to the SDLs, whereas it was the opposite for Roger. An example of this can be seen in the fact that Roger attended the pedagogical discussion session, but Paul did not.

The greater exposure that Roger had to the SDLs, the discussions he was able to have with them, enabled him to develop mutual engagement, a joint enterprise and elements of a shared repertoire. The inverse of this was seen with Paul not developing these aspects of a CoP with the SDLs. Paul acknowledged that he did not develop relationships with the SDLs but commented on time restrictions being a factor. His belief was that if time had permitted, he would have been able to develop such relationships. Likewise, Roger raised issues with time, despite having spent longer with the SDLs than Paul. He said this would have further enhanced their relationship and he would have been able to trust them more to take on the

roles and responsibilities he had envisaged for them. Furthermore, Paul and Roger's comments seemed to support the principal's wider view on the introduction of the SDLs. She talked about how the more the teachers worked with students in active roles, the less hesitant they would become.

This has implications for how a SDL strategy is set up and the length of time it is planned to run for. It also has implications for what exactly happens when working with the SDLs and points to a need to provide opportunities and time for relationships to develop between the teachers and SDLs; for example, providing discussion opportunities, situations where sharing can occur and questions can be raised as opposed to SDLs presenting or instructing teachers. The suggestion is that greater influence of teachers' knowledge and practice is likely to occur with more time planned for teachers to work with the SDLs and build relationships with them.

3. **There are limitations to the influence SDLs can have on teachers who consider themselves relatively high in confidence and skills in using technology. The effectiveness of introducing SDLs on influencing these teachers seems to be linked to their willingness to develop a mindset when working with SDLs.**

This case study featured a teacher, Roger, who considered himself relatively high in confidence and skills in using technology before the commencement of this research study. He then worked closely with the SDLs, and his knowledge and practice were seen to be positively influenced by them in respect of integrating technology. This was despite already being skilled and confident.

Although this case study has already provided evidence and discussed that the roles that the two teachers took in their team facilitated Roger to be in a position to work more closely with the SDLs and this could be said to give him greater potential to be influenced by them, there were other factors to do with his mindset and his approach to working with them that meant his knowledge and practice were influenced. He was seen to invest time with the SDLs, to discuss ideas and question them on topics related to his thoughts and beliefs. There

was evidence of his taking on the advice of the SDLs and being guided by them. However, Roger was also clear about where he saw limitations in the SDLs' influence, believing he had superior knowledge and experience so as to follow his own plans as opposed to taking on the SDLs' advice.

The implications of these findings are twofold. Firstly, the introduction of SDLs can positively influence teachers who consider themselves relatively high in confidence and skills in using technology; therefore, those teachers should be included as participants. However, the influence may be not as great as on teachers with lesser confidence and skills in integrating technology. Secondly, in order for these teachers to be influenced by the SDLs, they need to have a learner mindset, a belief that they can learn from the SDLs and approach involvement with them accordingly. This may mean that prior to teachers being involved with SDLs, such expectations about learning from the SDLs is clarified or, at the very least, teachers are given helpful information on how to get the best out of their involvement with the SDLs.

Chapter 6: Case study 2 – Marg & Faith

This case study analyses two teachers who were new to the school, new to teaching PBL and who joined the PBL teaching groups after it had begun. Using a CoP lens, it will be shown how both teachers can be considered newcomers in a CoP working together in a teaching team. Having established this, the case study will examine their reliance on more experienced teachers and the SDLs when trying to integrate technology. This will, firstly, reveal challenges to how the traditional newcomer/old-timer relationship works in Wenger (1998) and, secondly, offer a different perspective on the idea of distributed TPACK.

Through a CoP lens, this case study will again highlight the significance of teachers' identities and trajectories, but this time the focus is on knowledge and practice. Using a TPACK lens, Marg and Faith's identities and trajectories will be shown to contribute to their TPACK development. How knowledge development relates to changes in their teaching practice will then be shown. The significance of developing a CoP with SDLs will again feature in this case study, with mutual engagement and joint enterprise between the teachers and SDLs all contributing factors. It will be shown how a lack of planning with the SDLs and working with them without sufficiently developing relationships negatively affected the degree of the SDLs' influence on the teachers' knowledge and practice. Lastly, this case study will use a TPACK lens to look at SDLs providing in-class assistance, working with students and alongside teachers. By doing so, it will highlight the role that contextual factors play; certain factors can enable SDLs to easily integrate into classrooms, but others need to be recognised and planned for.

6.1. Two newcomers in a teaching team

This section will commence with an examination of data that highlights Marg and Faith as new teachers at the school at the outset of this research study. It will then consider how this positioned the teachers as members of a teaching team CoP, highlighting that this case study is about two newcomers working in a teaching team. From this basis, data will show how they

sought assistance from specific teachers and the SDLs in respect of trying to integrate technology. This will prompt discussions on the descriptions and examples Wenger (1998) provided for newcomers working with old-timers. Moreover, the approaches used by Marg and Faith in providing students with learning on new technologies will challenge the notion of old-timers providing an apprenticeship for newcomers. Despite opportunities for developing TPACK and practice from more experienced teachers and SDLs, both newcomer teachers showed little advancement in respect of integrating technology. This demonstrates how reliant the concept of old-timers developing newcomers is on active and willing mentoring. It shows how a lack of development in a mentor/mentee relationship between old-timers and newcomers can lead to outcomes for newcomers that are very different from the concept of apprenticeships that Wenger described.

The final part of this section will move from a focus on practice to the use of CoP as a lens. It will also look at the concept of distributed knowledge through a TPACK lens, focusing on how knowledge was shared with the teachers in this case study in respect of the crucial role that the SDLs played. It will briefly look at the sharing of knowledge between the teachers. However, the main aspect of distributed TPACK discussed in this case study will involve how the SDLs shared knowledge with the teachers, what impact this had on the teachers and how this study adds to research in this area.

Responses to the pre-involvement survey highlight how of all the teachers involved in this research study Marg and Faith had the lowest number of years as teachers and the lowest numbers of years at the school. Summarising from the data in Table 3, demographic details for Marg and Faith are provided in Table 7 below:

Table 7: *Marg and Faith's demographic details*

Name	Years teaching	Years teaching at the school	Qualified to teach in	Role in school	Experience in PBL	Involved in PBL planning	Joined PBL team
Marg	1	½ year	Humanities, English	Teacher	No	No	Term 4
Faith	2	1	English, Health	Teacher	No	No	Term 2

Table 7 shows that Marg and Faith had only just joined the school and the PBL team. It also shows their relative inexperience in the profession. Lastly, it is also worth pointing out that neither teacher was involved in planning for PBL. They both joined the PBL team at least a term after it commenced. In other words, they were involved in teaching PBL after it had already been planned and taught by other teachers, taking over a class of students from another teaching team. The full implications of their lack of involvement from the inception of PBL are beyond the scope of this research study. However, these demographic details offer an insight into the teachers' identities, which will be discussed in later sections. At this juncture, the data in Table 7 provides the foundations for commencing a discussion about Marg and Faith as newcomers working as a PBL team.

The previous case study highlighted how Paul and Roger's relative experiences and aspects of their identities were far more relevant in determining how they participated in their teaching team than a reliance on the descriptions of newcomers and old-timers from Wenger (1998). However, in that case study, the data revealed ambiguities around what should be considered as experience. Both teachers were very inexperienced in PBL. Roger had been teaching far longer than Paul, but Paul was not new to the profession. In other words, this reveals that Wenger's binary description of newcomers and old-timers does not seem to fit. It seems better to understand membership of a CoP as a state of relativity where, relative to any one member, others are newer or older in the CoP. However, the data is not the same for Marg and Faith as it was for Paul and Roger. The data in Table 7 shows that Marg and Faith had limited experiences in the teaching profession, limited experiences at the school and

limited experience of PBL. Hence, even though Paul and Roger's case study revealed ambiguities in defining experience and challenged the notion of newcomers and old-timers, Marg and Faith can be seen as newcomers to CoPs around the teaching of PBL.

Newcomers to CoPs are on the periphery, only participating partially (Wenger, 1998). According to Blåka and Filstad (2007), this peripheral position creates its own issues: "The challenges for newcomers in general are to handle the transformation between different cultures and within different communities of practice." (p. 67). Hence, not only are there the factors of relative inexperience as teachers, lack of experience teaching in a team and lack of experience in PBL to consider in terms of Marg and Faith but also challenges with their having to adapt culturally to a new school, its staff and students. It is likely that there would be numerous CoPs that they will be exposed to. However, it could also be said that changes in "cultures" and "within different" CoPs create opportunities as well as challenges. The teacher groups and relationships illustrated in Figure 6 outline structures around the teaching of PBL, featuring all the teachers involved. Although the focus of this case study is the CoP around Marg and Faith working as a pair in their teaching team, echoing the comments of Blåka and Filstad, there are other influences to consider. In this research study, the SDLs offered one such influence for Marg and Faith. However, as the data will reveal, there is also the influence of Paul and Roger, who made up their PBL teaching group, to consider. Thus, the next section will use a CoP lens to discuss Marg and Faith as two newcomers and how they participated in a teaching team CoP influenced by the SDLs and by Paul and Roger.

The influences of experienced teachers and SDLs on newcomers

The influences of both experienced teachers and the SDLs on two newcomers working as a teaching team can be seen from Marg and Faith's practice. The decisions they made in planning to teach and the way they team-taught 3D design software to their PBL class – all these factors reveal how they were influenced. This section firstly looks at evidence of how PBL students were introduced to the technology and the teachers' roles in this. It then focuses

on the teachers' involvement in assisting students as they developed their ideas and skills using the technology.

It can be seen in Figure 7 that both Marg and Faith were involved in the software training session. They were introduced to the 3D design software that was to be used in the upcoming PBL classes prior to commencing teaching with the technology. During these SDL-run sessions, they were trained and assisted in understanding how to use the technology, some of the capabilities of the software and the purpose of the software. However, despite this training session, from the outset of teaching the technology to their PBL students, the task of educating students on how to use the software was largely given over to others.

Students in Marg and Faith's PBL class were introduced to 3D design software in Paul and Roger's class. Both PBL classes were timetabled at the same time, and observations were made of a group of students from Marg and Faith's class joining Paul and Roger's class and being shown the basics of the software by the SDLs and Paul and Roger (Researcher observations, 7 November 2017). In the reflective interviews, Marg was asked about this. She said, the students in their PBL class "did an introduction with Paul and Roger because they have more skills and knowledge than us basically" (Marg, interview, 5 December 2017). This seems to show how she made a judgement on what was best for the students in her PBL class in respect of being introduced to the technology. She recognised that two teachers with more "skills and knowledge" using the technology was a better option than herself and Faith to provide the necessary introductory sessions to the students.

Faith was also asked about this session, introducing the technology to their PBL class. She replied, "we had organised within our PBL group that they were going to introduce the software because they felt a lot more confident with it than we did" (Faith, interview, 5 December 2017). Her reply confirms Marg's judgements in respect of what was considered to be the best approach for the students in being introduced to the technology, recognising that Paul and Roger were better suited for that role. However, Faith's comments reveal more

about this arrangement, showing that this approach, with the technology introduced by Paul and Roger, was "organised". Although none of the teachers offered any expansion to their comments, there is a suggestion that the four teachers in the teaching group discussed this to some degree or, at the very least, Paul and Roger were either asked to perform such a role or offered to do so. In other words, it was not something spontaneous. Instead, it was the outcome of how Marg and Faith felt about their own knowledge and practice; how best to approach introducing the technology to their PBL class.

The arrangement made for Paul and Roger to introduce the 3D design software to Marg and Faith's PBL students can be aligned to what is described in Wenger (1998) around the participation of old-timers and newcomers. He talked about how old-timers "spend energy introducing newcomers into the actual practice of their community" (p. 100). This can be in various ways that affect "actual practice" including old-timers giving "special assistance" (p. 100) to newcomers or newcomers having "lessened production pressures" (p. 100). From Faith and Marg's comments, it is clear that both teachers recognised Paul and Roger had relatively more "skills and knowledge" and more "confidence" than they did with the technology. With Paul and Roger providing the introduction to technology to Faith and Marg's students, either of Wenger's interpretations of events could be justified.

Furthermore, Wenger (1998) described in the example of claims processors how old-timers and newcomers work together building a communal memory. This enables members of a CoP to create ways of reconciling work requirements with the actual challenges that the work itself presents. In doing so, members can participate in the community and complete the work that is required in an organisation without having to know everything. This, in turn, helps to integrate newcomers (Wenger, 1998). As already discussed in Section 6.1 using data from Table 7, Marg and Faith were very inexperienced in a variety of ways at the outset of this research. They were newcomers on the periphery of CoPs around the teaching of PBL and likely facing the cultural challenges newcomers encounter in such positions (Blåka & Filstad, 2007). Given this, it seems understandable that Marg and Faith would utilise the

support of more experienced colleagues in a specific area in which they lacked confidence, skill and knowledge. In doing so, this provided the students with the teaching required in introducing the technology. It also reconciled work requirements in a similar way to how newcomers and old-timers in claims processing operate, according to Wenger (1998).

Using the CoP lens in this section has, to this point, enabled Marg and Faith to be seen as newcomers. They engaged with Paul and Roger, having them provide introductions to technology with their PBL students. This seems to align with how newcomers and old-timers typically operate in a CoP, according to Wenger (1998). However, there is one marked contrast between what has been described in this case study and Wenger's newcomer/old-timer relationship, in respect of the apprenticeship and mentorship aspects. The next few paragraphs will distil the meanings of apprenticeships and mentorships through a CoP lens and how this highlights a contrast between the descriptions in Wenger (1998) and events in this case study.

The issue of mentorship for newcomers working with SDLs

The concept of apprenticeship was a key element of Lave and Wenger's (1991) work on situated learning, where CoP theory provided a way to understand learning that occurs in a social environment; central to this theory were the interactions between novices and experts. Lave and Wenger described a process where newcomers, also known as apprentices, develop more established roles and more legitimate peripheral participation in a CoP and experience identity transformation as their participation changes. In Wenger (1998), identity and practice became more of the focus when looking at the relationships between newcomers and old-timers:

> Our purpose was to articulate what it is about apprenticeship that seemed so compelling as a learning process. Toward this end, we used the concept of *legitimate peripheral participation* to characterize learning. We wanted to broaden the traditional connotations of the concept of apprenticeship – from a master/student or mentor/mentee relationship to one of changing participation and identity transformation in a community of practice. The concepts of identity and community of practice were thus important to our argument,

> but they were not given the spotlight and were left largely unanalysed. In this book I have given these concepts center stage. (p. 11)

Wenger's comments highlight how the concept of apprenticeship remains significant when considering old-timers and newcomers. In addition, they provide acknowledgement for mentorship being a part of apprenticeship where, in the final two sentences of this quote, it is clear that using a CoP lens in this case study should target data that shows the development of the newcomers' identity and practice. Hence, the main issue is not whether a newcomer/old-timer relationship existed in this case study. Instead, there should be evidence that, through the arrangements made between Marg, Faith, Paul and Roger, Marg and Faith developed their identity and practice.

Looking closely at how the PBL students in this case study were introduced to the technology, they were taught in a different location with different teachers, Paul and Roger. In other words, Faith and Marg were not involved in these teaching sessions and, as such, did not take the knowledge they had gained from the software training session and use that in their teaching practice to introduce the technology. Such conditions do not seem to facilitate the concept of newcomers being mentored by old-timers, as described in Wenger (1998). The conditions differ from those described by Wenger in a number of different ways, which the next few paragraphs will discuss.

For newcomers to have legitimate peripheral participation that "captures important conditions under which people can become members of communities of practice" (Wenger, 1998, p. 100), they need to have peripherality and legitimacy. Peripherality provides a diluted version of participation but it must give "exposure to actual practice" (p. 100). Newcomers need to have opportunities to develop mutual engagement with those involved in the practice, what they do, "their negotiation of the enterprise, and to the repertoire in use" (p. 100); in other words, develop their position as members of the CoP.

Applying each of the newcomer's development needs as Wenger (1998) describes for peripherality, there are clearly elements Marg and Faith would not have had the opportunity

to cultivate. With the introductory sessions being led separate from Marg and Faith in both physical location and teaching input, it is difficult to see how they could have had such exposure to practice involved in introducing 3D design. Being separate from the teaching of technology to students, uninvolved in the introductory sessions, Marg and Faith did not interact with the members of their community, Paul and Roger, which would have developed mutual engagement. Having organised with Paul and Roger to introduce the technology to their students, Marg and Faith could be said to be acting on the enterprise as they were working together with their PBL group towards a common goal. However, again, due to a lack of involvement in teaching sessions where the technology was introduced, it is hard to see Marg and Faith developing a shared repertoire, including such aspects as techniques, shortcuts and jargon around 3D design. Thus, all in all, it is difficult to conclude that Marg and Faith would have had peripherality leading them to fuller participation.

In respect of legitimacy, "newcomers must be granted enough legitimacy to be treated as potential members" (Wenger, 1998, p. 101). Looking at CoPs for teachers across the school and for all teachers of PBL, it could be that Marg and Faith were granted sufficient legitimacy, but that would require analysis of those communities and the membership of both teachers within them. However, those CoPs are not the areas of focus here. Instead, it is the CoPs around the specific PBL teaching team of Marg and Faith and the PBL teaching group including Paul and Roger. When the spotlight is trained on to the integration of technology into the practice of these CoPs, there appear to be stark differences. According to Wenger (1998), when providing enough legitimacy to newcomers, "inevitable stumblings and violations become opportunities for learning rather than cause for dismissal, neglect, or exclusion" (p. 101). The way that the introductions to technology for students were organised in the PBL group with Paul and Roger taking those sessions suggests that Marg and Faith were excluded or, rather, they excluded themselves. As a result of such exclusions, opportunities for the learning that Wenger referred to were not available to Marg and Faith. Thus, in respect of integrating technology into their practice, Marg and Faith were unlikely to

have been granted sufficient legitimacy.

The preceding paragraphs have shown that Marg and Faith did not really have the conditions of peripherality and legitimacy when their students were introduced to the technology, as Wenger (1998) described. This is despite the involvement of Paul and Roger in roles that follow what Wenger characterised as old-timers mentoring newcomers. Not being involved in introductory sessions to technology would not lead to Marg and Faith's fuller participation with technology integration. As a result, they were not on inbound trajectories, as newcomers need to be, to achieve full participation in a CoP.

However, the focus thus far has been solely on the introductory sessions. As "practice is an ongoing, social, interactional process, and the introduction of newcomers is merely a version of what practice already is" (Wenger, 1998, p. 102), evidence of how Marg and Faith's practice developed beyond these introductory sessions should be considered. Students had to advance beyond the introductory sessions, use the technology and develop their 3D design skills during the PBL classes. The PBL classes were taught by Marg and Faith. Hence, there is the question of whether the software training session resulted in any developments in technology-integrated practice for these two newcomer teachers, despite not being involved in introducing the software. This question can be answered using evidence from relevant researcher observations and from the teachers' comments. These illustrate the way Marg and Faith approached teaching students using the 3D software in their PBL classes. However, at this juncture, the role of SDLs providing in-class assistance is of particular significance as they were heavily involved in Marg and Faith's PBL classes when students were using 3D design. All of these matters are discussed below.

Developments in newcomers' technology-integrated practice and the role of the SDLs

After being introduced to the software by Paul and Roger, the SDLs were invited into Marg and Faith's PBL class to provide in-class assistance. They were seen to work with

students developing 3D models, and this work was largely independent of the teachers: “SDLs working with groups of students while teachers deal with other matters” (Researcher observations, 30 November 2017). This appears to continue the trend seen in Section 6.1. (The issue of mentorship for newcomers working with SDLs) in respect of Marg and Faith’s lack of involvement in teaching with technology. Paul and Roger led introductory sessions on 3D design to students from Marg and Faith’s PBL class; but beyond these introductory sessions, teaching the returning students was an opportunity for Marg and Faith to develop their practice in the use of technology, in this case, 3D design. The observations suggest that this did not occur, though. Instead, with the SDLs working with students and teachers attending to “other matters” in the classroom, there is little to suggest that Marg and Faith’s practice in respect of integrating technology could advance through their teaching this PBL class.

In the reflective interviews, Marg was questioned about the observations made on the SDLs assisting in her PBL classes. She was asked if she simply handed groups of students over to the SDLs rather than work alongside them. Her reply was that this did occur, particularly when she felt other students needed her: "Yes. They would take responsibility for some of those kids if we got called away to go to others” (Marg, interview, 5 December 2017). Marg’s comments do not provide complete clarity or full support to the researcher observations as she talked about the SDLs taking responsibility for working with PBL students on 3D design using the conditional “if”. In other words, there is no information provided as to how often these events occurred or how much they affected her, nor the length of time Faith spent working with these particular students. The researcher observations represent a snapshot of what was witnessed over a relatively short period of time in the lesson. They do not provide a complete picture of the whole lesson where the teacher may have spent some time with these students. They do, however, affirm the idea that Marg and Faith “handed over” the students to the SDLs giving them “responsibility”. This suggests that the teachers’ roles working with the students on 3D design was secondary to that of the SDLs,

whose sole responsibility in the lesson was to assist students using the software.

Further comments from Marg and Faith during the reflective interviews contribute to the argument that their practice did not really develop in respect of teaching the students using technology in their PBL class and the impact of taking a secondary role with the SDLs having "responsibility". Faith described how she struggled helping students:

> I will try and sit next to the kids who went to Roger's session and have done a 3D design model and I will try and move something for them, help them and it will be like, "I just stuffed up the whole thing, I'm really sorry I tried to help you but I'm not very good with this". (Faith, interview, 5 December 2017)

Marg did not offer such a personal reflection but echoed some of the struggles Faith referred to: "We tried to check in with them and see how they were going and gauge how well they were going but we are no experts, so it was difficult" (Marg, interview, 5 December 2017). Both teachers pointed to having tried to work with students developing 3D design models but also demonstrated difficulties they had in doing so. They referred to their own lack of skills and how limited their teaching roles were with these students.

It is clear that the researcher observations and the teachers' comments in the previous paragraphs bring into question how much, if at all, Marg and Faith's practice in respect of technology developed in their PBL classes. Returning to Wenger's (1998) CoP lens looking at peripherality and legitimacy and whether there were sufficient opportunities for the two newcomer teachers to develop mutual engagement, the focus shifts to some degree from a mentor/mentee relationship with Paul and Roger to the involvement of the SDLs. However, issues of Marg and Faith developing a CoP in respect of integrating technology in their PBL class were still present as they were during the introductory sessions.

Section 6.1. (The issue of mentorship for newcomers working with SDLs) described Wenger's concepts of peripherality, legitimacy and mutual engagement. It was shown that Marg and Faith were not really in positions to develop as would be expected of newcomers, given their lack of involvement in the introductory sessions for teaching 3D design to their

PBL students. This appeared to continue when the students returned to their PBL classes. The involvement of the SDLs did not seem to enhance opportunities for mutual engagement with the technology nor was there any evidence of building a shared repertoire, as newcomers developing practice and being on an inbound trajectory in a CoP would typically have (Wenger, 1998). The evolvement of practice in a CoP relies on situations where "members interact, do things together, negotiate new meanings, and learn from each other" (Wenger, 1998, p. 102). There is very little to suggest any of this occurred in the PBL classes in respect of teaching 3D design.

To summarise what can be seen from Section (The influences of experienced teachers and SDLs on newcomers; The issue of mentorship for newcomers working with SDLs; Developments in newcomers' technology-integrated practice and the role of the SDLs), this case study provides an opportunity to look at two newcomer teachers who were trained in using specific technology with the intention that they would develop their teaching practice to integrate this technology in their PBL class. Firstly, they sought assistance from their more experienced peers, which on first impression seems to follow what would be expected from a typical mentor/mentee relationship in a CoP, according to Wenger (1998). However, the reality is in contrast to what Wenger described, as Marg and Faith were not mutually engaged in the process of introducing the technology to their PBL students. Secondly, they had in-class assistance from the SDLs as students returned to their PBL class after the introductory session on 3D design. This again could have been a situation where their practice in respect of integrating technology developed as they assisted students and worked in collaboration with the SDLs – a CoP process of learning from each other (Wenger, 1998). However, this seemed to be prevented by an indeterminable causal nexus consisting of giving responsibility to the SDLs to work with the students on the development of their 3D designs and a self-professed lack of skills in and confidence with the technology.

Given how events unfolded for Marg and Faith, this case study reveals not only different perspectives for newcomers working with more experienced teachers than how Wenger

(1998) described such relationships but also how the roles that those involved take influence the development of practice. What can be seen here is a lack of development in practice involving technology for two newcomer teachers, where more experienced teachers and the SDLs were involved. The main stumbling block to the development of practice seems to relate to how little Marg and Faith were actually involved in teaching with technology and collaborating with their more experienced peers and with the SDLs in the development of skills in 3D design. Hence, in relation to the research question *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?,* this case study has revealed that issues regarding the roles teachers take and the way they work with SDLs are important in determining the degree of influence the introduction of the SDLs can have on them. A lack of being mutually engaged and teachers not actually being physically involved in the development of their practice are significant factors.

To date in this case study, the whole of Section 6.1 has utilised CoP as a lens with little regard for the teachers' TPACK, despite continual reference to their development (or lack thereof) in respect of technology integration. The conclusions offered above highlight how a lack of mutual engagement and lack of involvement in developing teaching practice refer to practice, but using the TPACK lens offers the chance to examine knowledge. In particular, the events in this case study and the way Marg and Faith worked with their peers, but more importantly with the SDLs, offer insight into the concept of distributed TPACK. This will be covered in the last of the subsections of Section 6.1 below. It will commence with a return to what research has shown in this area through a brief synopsis of related discussions from the literature review.

Newcomers and distributed TPACK

Distributed TPACK "claims that when teaching with technology the knowledge required does not reside in just the teacher's head but is rather distributed within a complex system of

resources that includes students" (Di Blas, 2016a, p.67). This lends support to the belief that knowledge can be shared. Such a "system of resources" can involve people; and in respect of this research study, there were both teachers and SDLs involved. The development of TPACK may be based on the belief that some relevant knowledge is held not by an individual but by others who are resources utilised by a teacher in their practice.

The precise area of focus for this research study is the sharing of knowledge between students in the role as SDLs and teachers to enable more effective use of technology by the teachers. Examination of distributed TPACK where students influence teachers has featured only in a small number of research papers (see Section 2.1.– Knowledge development in TPACK). To summarise the main points in that section, it was clear that the researchers involved saw potential for students to affect teachers' TPACK; but those papers dealt with different scenarios from the focus of this thesis or different education sectors than a secondary school setting. Di Blas and Paolini (2017) provided evidence that teachers consider students they teach to be a valuable source of TK (Table 1). However, theirs was not a planned strategy as it was in this research and, as they acknowledged, the setting was not in a school or an actual classroom environment. Sharing TPACK between teachers and students was the focus of Jones et al. (2015) and, as with Di Blas and Paolini (2017), there was a call for further research in this area. The work of Jones et al. and much of the research in distributed TPACK between teachers and students has been in a higher education setting, though. Hence, through the use of case studies, there is the opportunity to further research the sharing of TPACK, especially students sharing knowledge with teachers, with an examination of how two teachers' TPACK is affected when working with SDLs in a secondary school setting. However, firstly, distributed TPACK will be discussed with the sharing of knowledge between more experienced and newcomer teachers as there are some important points observed from that angle.

This case study, to date, has described a scenario where two newcomer teachers worked with more experienced teachers, Paul and Roger. These more experienced teachers took on

roles in introducing technology to students who were then taught by the newcomer teachers, Marg and Faith. In other words, Paul and Roger used their TK and TPK to assist colleagues in their practice. This scenario appears to support the assertion that TPACK is not individual knowledge but is, instead, derived from a support network that teachers typically have access to and are influenced by (Di Blas, Fiore, et al., 2014; Di Blas, Paolini, et al., 2014).

Discussions on distributed TPACK in Section 2.1. (Knowledge development in TPACK) featured the research of M. Phillips et al. (2017), who challenged the idea that all forms of knowledge in the TPACK framework should be treated in the same way. With that argument in mind, I drew attention to TK specifically and I showed how Jones et al. (2015) aligns to the views of M. Phillips et al. (2017), namely that technology (and, as a result, TK) is ever-changing. Given the dynamism of TK, it is common for teachers to be lacking in such knowledge, influencing them to develop their TK through distributed means (Jones et al., 2015).

The students who were introduced to 3D design by Paul and Roger returned to Marg and Faith's PBL class to develop their 3D models. In those classes, the SDLs provided in-class assistance working specifically with students using the technology. In other words, the SDLs used their TK and TPK to assist the teachers in their practice. The SDLs were seen as having specific technical knowledge and software training that they could use to assist the students in the PBL class. This again seems to back the concept of distributed knowledge: Marg and Faith utilised a support network, but in this case, the support came from the SDLs, not the teachers. Furthermore, having in-class assistance from the SDLs to work with the students using technology could be seen to endorse the views of Jones et al. (2015) and M. Phillips et al. (2017) that TK is a unique form of knowledge in the TPACK framework.

However, there are issues with newcomers having support from more experienced teachers in the introductory session on technology as well as the SDLs providing in-class assistance following the introductory session, amounting to distributed TPACK. Firstly, Paul and Roger

introduced 3D design to students from Marg and Faith's class, in a separate location, without the two newcomer teachers in attendance or involved in any way. This raises questions as to how this could be seen as sharing knowledge when it appears as if the knowledge remained with those more experienced teachers. With Marg and Faith's lack of involvement in the introductory session, it is difficult to see how their TK or TPK could have developed from the support that Paul and Roger provided. Secondly, the SDLs were largely left to work independently with the students using 3D design software when they provided in-class assistance. Again, this meant little involvement from Marg and Faith; thus, the same argument regarding their TK or TPK not developing could be used.

Support for the idea that they did not develop TK (and to some degree, TPK) can be seen in how Marg and Faith view their ongoing weaknesses in using the technology. Section 6.1. (Developments in newcomers' technology-integrated practice and the role of the SDLs) provided evidence that neither teacher considers themselves to be knowledgeable in 3D design, despite having been trained by the SDLs early in this research study and having the support from more experienced teachers and from the SDLs. Talking about their capabilities using 3D design software, Faith said she was "not very good" (Faith, interview, 5 December 2017). Marg said both she and Faith were "no experts", highlighting that Paul and Roger had "more skills and knowledge" (Marg, interview, 5 December 2017). In addition, further comments during the interview add to this argument: Marg talked about "being so unfamiliar with the software and the programming" (Marg, interview, 5 December 2017); Faith referred to being "uncomfortable" (Faith, interview, 5 December 2017) with the technology. Although none of these quotes expressly state that they were lacking knowledge, there is, arguably, sufficient relevant information provided to question the development of their TPACK.

This aligns to a point that was made in Section 2.1. (Knowledge development in TPACK) regarding the events in Di Blas, Paolini, et al. (2014) and in Di Blas and Paolini (2017). In both papers, it seemed as if the knowledge could be seen to stay with the person assisting rather than being shared with the teacher. This was described at one point as the teacher

having “offloaded the technology responsibility” (Di Blas, Paolini, et al., 2014, p. 2460) due to lack of TK. It could be argued that the role both Paul and Roger as well as the SDLs play in supporting Marg and Faith is akin to “offloading”, where others take on the responsibility of ensuring the students are taught how to develop 3D models using the software provided. The question is whether such “offloading” results in knowledge not being distributed. The multiple statements made by Marg and Faith describing their lack of knowledge and skills in using the software seem to answer that question. Through lack of involvement with their support network when teaching with technology, knowledge was prevented from being shared. TPACK was not distributed between Marg and Faith, their more experienced peers or the SDLs.

To conclude, this case study has provided an insight into two newcomer teachers in a teaching team who had initial training on the use of technology with the intention that they would teach this to their students in a PBL class. They utilised support in two ways: Firstly, two more experienced teachers in their PBL teaching group introduced their students to 3D design. This provided an opportunity for an old-timer/newcomer relationship akin to a CoP apprenticeship, as described by Wenger (1998). However, such a relationship relies on mentoring. The newcomer teachers needed to be involved in the process, engaged in the practice and in a process of learning. This did not occur, as the students were taken away from the main group and introduced to the technology without Marg and Faith’s involvement. Thus, due to the approach used in this case study, the concept of old-timer/newcomer that Wenger described did not really work. This shows how reliant the concept of old-timers developing newcomers is on active and willing mentoring, which is not discussed in Wenger (1998).

Secondly, students in the role of SDLs provided in-class assistance to the PBL students developing 3D models in Marg and Faith’s class. In many ways, this was again an opportunity for a mentor/mentee relationship; or in respect of technology, a different version of the apprenticeship concept that Wenger (1998) described. However, again this did not

occur. The way that SDLs worked with the students in the lessons they were involved in and how the teachers did not largely work with the SDLs or with the students using 3D design, resulted in both teachers not being mentored.

Both examples of how the newcomer teachers utilised support show that the concept of old-timer/newcomer mentoring as part of what was described as generational encounters by Wenger (1998) does not happen without certain conditions being met. These conditions are that newcomers have to be active and willing to accept mentoring in order to develop their knowledge and practice with technology. Without meeting these conditions, what Wenger described for newcomers gaining legitimacy in a CoP in respect of technology integration does not occur.

Using a TPACK lens, the events in this case study demonstrate attempts to share knowledge, particularly TK and possibly TPK, between the teachers and from the SDLs to the teachers. This, firstly, adds support to arguments that such knowledge can be treated differently in the TPACK framework, and secondly, that knowledge need not be held by an individual. Instead, it can be distributed around a network of support. Both more experienced teachers in their PBL teaching group and SDLs provide an opportunity to have elements of TPACK shared. However, again due to the approaches used in this case study with more experienced teachers and the SDLs, knowledge stayed with those who worked with the students, namely the more experienced teachers and the SDLs. The lack of active involvement of the newcomer teachers results in their knowledge not developing. Hence, any further research into distributed TPACK needs to consider how teachers are positioned to actually share knowledge rather than knowledge remaining with the more experienced teachers or with students with more expertise with technology. Having assistance with technology can mean that elements of TPACK remain with those assisting, if logistics are not thought through as to how the knowledge can be shared.

This section and, indeed, the whole of Section 6.1, have provided a stream of statements

made by Marg and Faith highlighting a lack of development in skills and knowledge of the technology used in this study. This has led to analysis using the TPACK and CoP lens, but there has been no consideration thus far on essential elements of the CoP model, teachers' identities and trajectories, focusing on how the lack of TPACK affects practice. This is the theme for the next section. Marg and Faith's comments from the reflective interviews have shown they consider themselves quite negatively in using the technology, despite training and assistance. Given Marg and Faith's self-denigration on using 3D design, there are grounds to discuss how the teachers' views of themselves could influence how their practice develops.

6.2. Identities and trajectories

Case study 1 provided an insight into the identities and trajectories of teachers in a teaching team. There are some links to what will be discussed in this section, but the focus was different. In Case study 1, Paul and Roger chose roles that reflected how they positioned themselves in the CoP, what they felt were important as teachers in their PBL teaching team and the trajectories they saw themselves on at the time. For Marg and Faith, the issue is about how issues of identity from present and past experiences alongside their trajectories affect the way they teach with technology, their classroom practice. To open this discussion, the next two paragraphs will provide a brief return to the relevant research in this area, a more complete version of which appears in the Literature review chapter.

Marg and Faith were both newcomers to the school and to CoPs around the teaching of PBL in the school. Newcomers are considered to be on inbound trajectories to full participation in a CoP's practices (Wenger, 1998). Wenger stated that a trajectory is "not a path that can be foreseen or chartered but a continuous motion – one that has a momentum of its own in addition to a field of influences" (p. 154). This proposed the idea that any member of a CoP, including newcomers, has flexible and continually changing developments, moving in trajectories that "incorporate the past and future in the very process of negotiating the present" (p. 155). This was summarised by M. D. Phillips (2014) as how "we identify

ourselves as much by where we have come from and where we believe we are going as by our current competence as members of a CoP" (p. 157). Hence, it is important not only to look at Marg and Faith in terms of their position in CoPs at the school but also how they participated during this research study. It is also vital that their identities are interrogated through what they said about past and present experiences as well as what they aspired to become.

Examination of the teachers' identities involves looking at data from a variety of sources. Responses to the pre-involvement survey as seen in Table 3 and in Table 7 provide basic quantitative data to judge Marg and Faith's status in the CoPs around teaching PBL at the outset of the research. It clearly shows them as newcomers and with little teaching experience. However, the data does not reveal how they viewed themselves and what experiences shaped their identities as teachers. Responses to the interview questions and observations made during the research study, on the other hand, delved more deeply into the teachers' identities and trajectories. These relate to the involvement of the SDLs, working in a teaching team and trying to integrate technology. Both teachers revealed their feelings in respect of their own TPACK development; and Faith, in particular, provided lots of information about what had happened to her when learning and using technology prior to this research study. This reveals strong links to some of the struggles she had with developing 3D design skills and the knowledge to teach the technology. These issues will now be discussed commencing with the way Marg and Faith were supported by their more experienced peers and the part that their identities played in this process.

As described in the previous section, students from Marg and Faith's PBL class were introduced to the software by Paul and Roger. The students then returned to the PBL class where there was in-class assistance from the SDLs. Support from more experienced teachers is, arguably, to be expected in such a scenario, and having the SDLs assist them was simply utilising the strategy set up for this research study. There were, however, underlying issues relating to Marg's and Faith's identities and trajectories that clearly influenced decisions to have other people help them. These are reflected in what was said in the reflective interviews.

Faith said:

> I think it was very much a discomfort thing for me and Marg. I was just like, "I couldn't even get this and I am expecting my kids to do it throughout the whole term!" So, immediately that was, erm, a really big challenge. I even said to Roger and Paul, "You guys seem to have got it really good. Me and Marg are not feeling comfortable". (Faith, interview, 5 December 2017)

Faith's comments offer an insight into the way she and Marg felt after being trained by the SDLs in using 3D design software. It seems that both teachers made their feelings known to each other regarding their "discomfort" with the technology and they shared that with Paul and Roger. Although she did not state that the sharing of these feelings then led to the introductory session being taken by the more experienced teachers and their lack of involvement from the outset in teaching the technology to their PBL students, there is a clear link. That link refers to how identity can affect practice.

Identity in a CoP involves both the interconnection of the individual and the community. Neither, on its own, defines a person's identity (Wenger, 1998). With reference to the workplace, Wenger described members of a CoP as "engaging in practice, but with a unique experience" (p. 146). This interconnectedness determines CoP members' experiences, interpretations, understandings and knowledge about their role (Wenger, 1998). Hence, by expressing such feelings of "discomfort", Faith revealed her thoughts and those of Marg and their feelings of unease in respect of understanding the technology and being able to integrate it into their practice. These are the experiences of the two teachers as members of the CoPs, as they engaged in the practice of developing TPACK to be able to teach 3D design to their PBL students.

Paul and Roger taking the introductory session with no involvement from Marg and Faith corresponds to Wenger's (1998) theory that identity is a unique experience of being engaged in practice. It is where "individuals and community are reifications" (p. 146) as the decision is made to have the students introduced to technology by teachers who are considered more knowledgeable in this area. This is an action that stems from identity. The action affects Marg

and Faith's practice in respect of technology. They did not further develop their TPACK from the initial training session to introduce the software to their PBL students.

Similarly, after the PBL students were introduced to 3D design by Roger and Paul and returned to the PBL class, the way the SDLs worked with these students on 3D design also meant that Marg and Faith did not develop their TPACK. Again, from comments in the reflective interviews, we can see that this does not seem to be accidental nor was it a result of the actions of the SDLs. Instead, the way that both teachers became almost reliant on the SDLs to help the PBL students develop their 3D models has foundations in Marg and Faith's identities. Marg said, "I had my own barriers in terms of being able to work with the programs, which stopped me being able to assist students with using the software" (Marg, interview, 5 December 2017). She did not go into more detail on exactly what those barriers were, but admitting to having such barriers, in itself, exposes that she perceived she was unable to teach the students 3D design. In other words, she conceded that she struggled with learning how to use the technology and that this prevented her ability to integrate the technology in her classroom.

The SDLs took on the role of assisting the PBL students with technology in the class. This was confirmed firstly by Marg, who said the SDLs "were actually helping people" (Marg, interview, 5 December 2017). Faith shared virtually the same account of events, describing that it was the SDLs who "were the ones actually helping the students, not me" (Faith, interview, 5 December 2017). These comments clearly give credence to the role that the SDLs had but, more importantly for this section, the lack of involvement both teachers had in this regard. With Marg revealing the fact that she had her "own barriers", attention can now be turned to Faith and what she revealed of her identity that resulted in her lack of involvement with the SDLs assisting the students in 3D design.

As we have seen in the previous section, Faith also went into a lot more detail about her struggles with developing TPACK with the 3D design software, providing a relatively in-

depth self-analysis. Firstly, she answered question about any barriers she had had using the technology as intended, by referencing the software training session and how she felt at that time:

> Erm, definitely for me it is my confidence. Like, I've not ever had much training at all in that area of 3D design software or any kind of design stuff like that so straight away, confidence wasn't high going into it. When we did the session, I wasn't getting it in the session either, like I was doing some sort of basic stuff but I just wasn't getting it to be honest. It was making me feel really uncomfortable and it was really hard to see everyone around me getting it so perfectly. (Faith, interview, 5 December 2017)

In this comment, she revealed both her identity in terms of not being confident with the technology but also how this related to past trajectories, not having "ever had much training". She also revealed pressure and feelings of discomfort in believing all other teachers in the session were not struggling in any way similar to her, as they were "getting it so perfectly".

Faith then related her struggles with learning the technology to wider issues with trying to establish herself as a newcomer to the CoPs around teaching PBL in a new school. She referred to its being "very much my own complex at the moment with PBL because I do feel that missing the chunk of the lead going into PBL" (Faith, interview, 5 December 2017). This revealed difficulties she saw in being a newcomer related to such areas as not having prior knowledge of the school, its systems, of PBL and the expectations of that approach. These difficulties put pressure on her, which she described as being "sort of on the back foot" (Faith, interview, 5 December 2017). Describing oneself as having a "complex" and being "on the back foot" when being trained are not aspects of identity that would be expected to provide strong foundations for developing knowledge and skills or encourage an individual to focus on developing a trajectory that sees them integrating technology in their practice.

According to Wenger (1998), "we are simultaneously dealing with specific situations, participating in the histories of certain practices, and involved in becoming certain persons" (p. 155). Faith has already revealed some of her past experiences, what could be said to be "histories of certain practices" she had struggled with when faced with technology. She

provided further insight on this: “Yeah, it’s just technology. I know all through school when we started to do digital design, erm, I’m really creative but I struggled” (Faith, interview, 5 December 2017). Clearly, experiences that go as far back as her own schooling made her uneasy about working with technology. Faith added, “When we started off this unit, knowing technology was going to be a big focus, I was like, ‘Oh God!’” (Faith, interview, 5 December 2017). As with Marg, Faith has barriers that existed before the software training session had even begun. Faith clearly related those to past trajectories.

However, as already discussed at the outset of Section 5.2, Wenger (1998) described identity as not reliant on how an individual sees themselves but revealed through practice, through the way individuals participate and reify the conditions around participation. Hence, it is important to focus on not just how both Marg and Faith saw themselves but also what their actions were in practice. By having the introductory session taken by Paul and Roger and having the SDLs assist students on 3D design in their PBL class, but more, importantly by both of these occurring independently of their own teaching of PBL, their TPACK struggled to develop. This is confirmed in the statement “It was more them taking the lead of actually supporting the students rather than involving us” (Marg, interview, 5 December 2017), referring to the SDLs’ in-class assistance. Marg and Faith had the SDLs take on some of the roles they could have taken in helping students in the lesson understand how best to use the software and ensuring they were progressing as expected. These roles are usually part of a teacher’s practice; as a result of neither involving themselves nor delivering instructions of how to use the 3D software from the outset, their practice in respect of technology integration did not really seem to advance.

In summary, this section has revealed circumstances where two teachers’ identities and trajectories can play a significant part in their TPACK development, with lots of evidence to show how knowledge can affect practice. Marg and Faith talked about their struggles with confidence, their fears and negative past and present experiences with technology. Due to these struggles and faced with the demands of students needing to be taught how to use the

technology, they made decisions and taken actions which have removed them from having to teach with the technology. This saw them involve their more experienced peers and the SDLs. In other words, their practice in respect of becoming more skilled in teaching with technology and integrating it in their practice did not develop in this instance. However, focusing on the SDL strategy used in this research study, there are further comments by Marg and Faith that provide different perspectives on why both had little influence on their students' learning of 3D design. These comments centre on CoP concepts of mutual engagement and joint enterprise and will be the focus of the next section.

6.3. Developing mutual engagement and joint enterprise with SDLs

According to Wenger (1998), "the first characteristic of practice as the source of coherence of a community is the mutual engagement of participants" (p. 73). Amongst Wenger's six sub-elements of mutual engagement, half of these – doing things together, relationships and community – are highly relevant in this section. Joint enterprise negotiation is "the second characteristic of practice as a source of community coherence" (p. 77). Wenger lists five sub-elements of joint enterprise. Of these, negotiated enterprise, mutual accountability and interpretations are very much related to how Marg and Faith worked with the SDLs. This section intends to focus on the way Marg and Faith worked with the SDLs, how they planned and prepared for assisting in the classroom and what actually transpired when the SDLs provided in-class assistance. Discussions on both mutual engagement and joint enterprise will reveal issues between the teachers and the SDLs that may have contributed to the way any possible CoPs involving both teachers and SDLs developed. A recount of the events leading up to and during the lessons when the SDLs provided in-class assistance provides a starting point for the discussion. This is supported by reflective comments made by Marg and Faith highlighting their struggles in working with the SDLs, which can be linked to mutual engagement and joint enterprise.

This research study involved the SDLs being given generalised training setting out the expectations of their roles and the sort of things that teachers on the PBL courses would require them to do. Likewise, the PBL teachers were given information at the outset on how the introduction of SDLs was intended to work, what would be involved and that the SDLs would provide software training and pedagogical and in-class assistance with the technology for the teachers and students. There was nothing prescriptive set out for the SDL roles during the in-class assistance element of this study. This was left to those involved to decide.

Marg and Faith had a team of SDLs assist them in lessons. These lessons followed on from the introductory sessions provided by Roger and Paul, where some of their PBL students had opted to create designs using 3D software. On their return to the PBL class after being introduced to the technology, this group of students were asked to sit together so that they could be easily identified and assisted. About 10 minutes prior to the lesson beginning, the SDLs were assembled in the teaching space. Just as the lesson was about to begin, I observed: "Teachers arrive and start the lesson" (Researcher observations, 30 November 2017). In other words, other than acknowledging the SDLs were there to assist them, Marg and Faith had very little interaction with the SDLs in the moments before the lesson began.

Faith provided a description of the scene at the start of that lesson. She talked about how she and Marg were:

> Both running really late. It was crazy. So, originally what it was there was supposed to be an intro where I came in to chat to them, "what do you need? What do you want from us? What are you going to be … what are you looking for?" Cos I did feel that I wasn't a 100% sure how to use them. (Faith, interview, 5 December 2017)

This reveals not only the hurriedness in starting the lesson but also that there was an intention for it to be done differently than it previously. Faith wanted to have a conversation with the SDLs, what can be described as informal planning of events and roles during the in-class assistance. However, it can also be seen from Faith's comments that she felt the need to have the "intro" with the SDLs due to ambiguities in their roles in the PBL lessons. This

suggests that there were uncertainties in the working relationships between the teachers and the SDLs in their expected roles.

Using a CoP lens with a focus on mutual engagement and joint enterprise to analyse Faith's comments, firstly, it is worth noting her reference to "use" of the SDLs. This suggests that there was far from a strong relationship developed between the teachers and the SDLs in that instance or that a sense of community had already been developed involving the SDLs. Wenger (1998) stated that, "a community of practice can become a very tight node of interpersonal relationships" (p. 76). That seems far removed from what was described for Marg and Faith with the SDLs who arrived to provide in-class assistance. Faith's desire to ask the questions quoted above suggests that there had not really been much in terms of doing things together, that is, an aspect of mutual engagement and one which builds the types of relationships that Wenger described. Similarly, looking at the relevant sub-elements of joint enterprise, namely negotiated enterprise, mutual accountability and interpretations, it seems highly unlikely, given Faith comments, that these had been developed with the SDLs. Some could have been developed had the "intro" that Faith referred to, happened, but that did not occur. In other words, any possible development of CoPs involving these SDLs and the teachers seemed to stall through not having the planned discussions.

Moving on from the period prior to the lesson into the actual lesson, having the SDLs involved for in-class assistance also did not work as intended from the teachers' points of view. Marg talked generally, saying it did not work "to its optimum point" (Marg, interview, 5 December 2017). Faith thought the SDLs were looking to her for affirmation on their roles during in-class assistance: "It was more, just, 'what more do you want from us?' and I was like, I thought it was the other way around" (Faith, interview, 5 December 2017). Faith's comments seem to indicate misunderstanding of how the involvement of the SDLs was supposed to work, which arguably continued from the lack of "intro" to the lesson, perhaps even a reluctance from either or both parties to take the lead. It is clear that there were issues with communication between the teachers and the SDLs.

Communication is not something that Wenger (1998) directly referred to in descriptions of mutual engagement or joint enterprise. It is, however, a vital aspect of the third dimension of practice, shared repertoire. According to Wenger, forms of communication developed in a CoP such as "words, artifacts, gestures, and routines are useful not only because they are recognizable in their relation to a history of mutual engagement, but also because they can be re-engaged in new situations" (p. 83). Thus, with an established CoP in which members are mutually engaged, one would expect to see those involved being able to call upon "words" and "routines" that can be adapted when experiencing something new. Marg and Faith were faced with the SDLs offering in-class assistance, and the SDLs were on the opposing side of the same scenario. However, neither party seemed to be able to articulate what should happen, how to proceed. Thus, it would be difficult to suggest that what was witnessed at this point were members of a CoP doing things together or working towards a joint enterprise they had negotiated.

There was also another factor from this lesson related to developing mutual engagement and joint enterprise between the teachers and SDLs that is worth mentioning. A group of SDLs were involved. All of them were given opportunities to participate in the strategy with different students chosen for particular roles due to the specific strengths they had developed. An example of this is the software training session, when those students who showed skills and confidence in presenting were selected to lead that session. Other SDLs were chosen to participate in other elements, such as in-class assistance. However, according to Faith, this created an added pressure as the SDLs who were present to assist in the PBL lesson were not the SDLs who had trained them in the earlier sessions: "If it had been those same SDLs that I had already known, I could already see how they had interacted with others, I knew exactly, I could start to see their strengths" (Faith, interview, 5 December 2017). This again relates to a sense of relationships not being developed, a sense of there not being mutual engagement between these particular SDLs and their teachers. More specifically, the lack of relationship between the teachers and the SDLs meant that there was little in the way of "relations of

mutual accountability" (Wenger, 1998, p.78) and that all parties would have little chance to be "engaged in actions whose meanings they negotiated with one another" (p. 73).

To dwell further on Faith's comments about the SDLs who provided in-class assistance being different from those she and Marg had received software training from, Faith said she "could start to see the strengths" of those SDLs she had been trained by. This is supported by Marg's comment, "I would have liked to have spent more time with the SDLs … not because I don't trust their ability but because it would have benefitted me" (Marg, interview, 5 December 2017) and by Faith, "I definitely felt that they weren't utilised as best they could have been" (Faith, interview, 5 December 2017). Although these comments do not make it clear whether they were referring to the SDLs they had in the software training session or those who provided in-class assistance, both clearly saw that there were opportunities for working more effectively with the SDLs in technology integration. These opportunities were not realised, though.

Looking at Marg and Faith's comments in respect of mutual engagement and joint enterprise, they could be interpreted as the potential for doing things together, building relationships and negotiated enterprise and mutual accountability between the SDLs and the teachers. According to Faith, certain aspects of working with the SDLs needed to be organised differently to overcome issues of mutual engagement and joint enterprise. As well as concerns with different SDLs from the software training session, she talked about having "something that was a bit more structured" (Faith, interview, 5 December 2017) and then added more detail suggesting "something more teacher led first and me instructing the SDLs, then having them a bit more in the future, then having a bit more the SDLs running something would have been a bit more beneficial" (Faith, interview, 5 December 2017). What Faith described arguably relates to the "intro" to the lesson, the time prior to the lesson commencing that she wanted to spend with the SDLs. However, it also described a tiered approach which would allow greater involvement of the teachers in the technology integration process, in teaching the PBL students 3D design.

Marg recalled the time when the SDLs were working with the PBL students: “I could see that they were working together but then if we sort of involved ourselves, it was almost withheld a little bit” (Marg, interview, 5 December 2017). She affirmed the lack of involvement of the teachers in the role that the SDLs were taking to provide in-class assistance but she did not offer a suggestion as to why that occurred. Faith, on the other hand, said, “Mine was definitely because I don’t know these SDLs and, and I’ve ever never really been able to talk to them or even know how they are at interacting with students, if that makes sense” (Faith, interview, 5 December 2017). She connected struggles with events during the in-class assistance to not having strength in the relationships with the SDLs.

From Marg and Faith’s comments, there is strong evidence that they believed there was potential for working together with the SDLs to develop from the software training to having in-class assistance more effectively, although it is not clear whether lack of preparation and planning or having the same group of SDLs in both sessions were the most influential factors. Indeed, it could be said that both were significant. It is worth noting at this point that neither Marg nor Faith had participated in the pedagogical discussion session offered between the software training and the in-class assistance. As the session was intended to focus on the sharing of ideas on approaches to teaching and learning with 3D design, it may have provided an opportunity for some planning and preparation in advance of the PBL lessons. Likewise, it would have offered the chance to gain exposure to more of the SDLs, prompting wider relationships to be developed or, at the very least, an understanding that there were a number of SDLs involved. Faith related what happened when she arrived at the start of the first in-class assistance PBL lesson: “all of sudden rocking up to class and seeing these three I’d never seen, never had any interaction with before. So, that was really hard” (Faith, interview, 5 December 2017). Her involvement in the pedagogy session might have reduced the possibility of this situation occurring.

All in all, the evidence in this section has revealed how a lack of planning and preparation alongside deficiencies in establishing relationships with the SDLs in the period leading up to

in-class assistance seemed to reduce the influence SDLs can on the teachers' TPACK. From their experiences, the two teachers suggested that they and the SDLs needed to be provided greater opportunities to be mutually engaged and develop a joint enterprise if they were to develop CoPs with the SDLs. Having more structure as to how the SDLs work in-class is a further suggestion offered in this section to improve the effectiveness of working with the SDLs. With a combination of these factors not in place, the SDLs' impact on teachers integrating technology in their classroom was far less than it possibly could have been.

It could be argued that there are parallels to be drawn between what has been described in this section and the view that a teacher can develop TPACK but then struggle to apply the knowledge in a classroom setting (Brantley-Dias & Ertmer, 2013; Doering et al., 2009). With the involvement of SDLs and teachers struggling with confidence in using the technology, there were clearly some different factors in this research study than those experienced in Brantley-Dias and Ertmer as well as Doering et al. However, Marg's comment, "I wouldn't even have had any knowledge whatsoever if I hadn't have had a chance to work with them" (Marg, interview, 5 December 2017), shows that she professed to acquire some TK during the software training session. Faith mentioned that "the first half of that initial training … was really easy to latch on to" (Faith, interview, 5 December 2017), which suggests she also gained some initial TK until "about half way through the session" when she "hit a wall" (Faith, interview, 5 December 2017). Thus, there is a suggestion that some of the difficulties came in applying that TK in their practice with their PBL classes.

Brantley-Dias and Ertmer (2013) and Doering et al. (2009) viewed the issues that some teachers have in applying TPACK knowledge in practice as a limitation of the TPACK framework. The latter of these research papers highlighted another constraint, namely contextual factors that can affect whether a teacher applies TPACK knowledge or not. From what has been described in this section, there were unique considerations, circumstances and events around the PBL classes. In other words, they did not work in a vacuum. These contextual complexities need to be acknowledged, analysed and understood in respect of

providing answers to the research question. Thus, the next section will discuss how contextual factors can influence the degree to which SDLs affect teachers' TPACK.

6.4. Contextual factors during in-class assistance

Section 2.1. (Knowledge use and context in TPACK) of the literature review discussed the research demonstrating the issues some teachers have in being able to turn TPACK into the practice of integrating technology into their classrooms. Two of these were cited in the last section: Brantley-Dias and Ertmer (2013) and Doering et al. (2009). However, as shown in Section 2.1. (Knowledge use and context in TPACK), debates on context feature quite heavily in a number of the papers on TPACK. The main contention is the issue of what should be seen as a contextual factor and what should not. It has been suggested that there are three levels of contextual factors that can be considered when using the TPACK framework: macro, meso and micro (Porras-Hernandez & Salinas-Amescua, 2013). More contemporary research has seen the TPACK model edited by its originator (see Figure 2) to label the outer circle as conteXtual knowledge (XK; Mishra, 2019). In doing so, there is the recognition that, "Contextual Knowledge would be everything from a teacher's awareness of available technologies, to the teacher's knowledge of the school, district, state, or national policies they operate within" (Mishra, 2019, p. 76). In other words, context encompasses many different factors at many different levels akin to the levels outlined by Porras-Hernandez and Salinas-Amescua. However, also by changing context to XK, "the outer circle becomes another knowledge domain that teachers must possess to integrate technology in teaching" (Mishra, 2019, p. 76). Hence, in this case study, there will be discussion not only of contextual factors but also of the teachers' knowledge and awareness of them.

As this research study involved training sessions, pedagogy sessions and in-class assistance, context could be looked at in a variety of situations. However, the main talking point in this case study has been, and remains, in-class assistance. Thus, the influence of contextual factors when teachers work with SDLs trying to integrate technology in the

classroom is the main focus. For the most part, this will involve factors that Porras-Hernández and Salinas-Amescua (2013) described at the micro level, as they relate to the actual events and conditions around teaching and learning. However, it will also be shown that decisions regarding pedagogical approaches made outside of the classroom can become contextual factors that affect teachers' development of TPACK. This section will see both the positives and negatives of the context. It will highlight how certain contextual factors can enable the SDLs to more easily integrate into classrooms working alongside the teachers, but other factors need to be recognised and planned for.

Looking firstly at how SDLs can integrate into classrooms, both Marg and Faith offered positive views on how the SDLs worked with the students in their PBL class. Faith viewed their role as "really helpful" (Faith, interview, 5 December 2017), but her comment was generic and not really insightful for looking specifically at in-class assistance. Marg, on the other hand, stated that she was, "100% confident in the SDLs knowledge and ability to be able to support students" (Marg, interview, 5 December 2017). When asked about factors that influenced the SDLs being able to work with the PBL students, Marg talked about the environment that the PBL class was typically taught in, the variety of people they were used to being exposed to during class and the team-teaching approach as factors. She referred to "the collaborative nature of the learning spaces", how "with the PBL classes, students are used to having different people in and out" and "if you were just used to being one teacher with a class all the time then to have these students come in might be a bit more invasive than what it was for us" (Marg, interview, 5 December 2017). All of Marg's observations can be seen as contextual factors that enabled the SDLs to work with the PBL students using 3D design in the classroom.

Marg's comments could be interpreted as her having XK of how the environment, the openness of the learning space and the approaches typically used to teach her PBL class were factors that would assist the SDLs in being able to work with the PBL students. In other words, because of her existing knowledge of the environment and the approaches to learning

her PBL class were accustomed to, she was confident of the SDLs being able to assist her PBL students successfully. However, one could argue that such an interpretation requires lots of assumptions to be made. A better interpretation of Marg's comments could be related to power. As mentioned in discussions in Section 6.1. (Developments in newcomers' technology-integrated practice and the role of the SDLs), Marg referred to the SDLs "taking responsibility" for the students developing 3D models (Marg, interview, 5 December 2017). This empowered role that the SDLs were allowed to take in the PBL lesson could be an example of a teacher "knowing how their organization functions, and how levers of power and influence can effect sustainable change" (Mishra, 2019, p. 77). Marg's awareness of how her PBL class were accustomed to seeing different people in their open, collaborative, learning environment aligns to knowledge of how the PBL class functioned. Having the SDLs take on roles working with students with very little teacher involvement could be said to show she has taken that knowledge and had the SDLs work in roles where they could directly influence the students' learning of technology.

However, Marg's positive comments on the SDLs mostly relate to their working with the students. There is little that seems to refer to the SDLs working with teachers. Only in the way she referred to "us" when she argued that the team-teaching approach meant the SDLs' provision of in-class assistance was less invasive, is there a suggestion that she was talking about her and Faith as well as the students. This is not surprising, given that there has been extensive commentary already in this case study on how the teachers had only minimal involvement with SDLs during the in-class assistance sessions.

Marg's comments on context when talking about the SDLs working with the teachers are in stark contrast to those she made about the SDLs working with the students:

> I think it would have been nicer with a smaller group. I think it would have been better for me as a teacher to have them in an environment where I could be more focused on what was actually happening with the 3D design and all that kind of stuff. Whereas because it is in the [Learning Hub], across that huge space with students all at different places, doing different things, it was hard to direct my focus on to that specific area of

> the lesson , particularly as we have some students doing 3D design but others not doing it and them some asking for other kinds of help. So, you are running around trying to get to them as well and it did take away what could have been gained from working with the SDLs and from seeing how they work with the students on the programs. (Marg, interview, 5 December 2017)

Firstly, this shows that contextual factors related to the teaching environment and the openness of the teaching space were challenges for Marg. These challenges clearly contributed to difficulties in working effectively with the SDLs in the classroom which, in turn, negatively affected the level of technology integration that she achieved. Secondly, there were contextual factors related to trying to provide assistance to students where there were some using technology and others who were not. This leads to questions about how approaches to teaching PBL can lead to issues for a teacher trying to integrate technology into their classroom. However, to understand this, PBL pedagogy must be unpacked.

PBL is described as where "students engage in real, meaningful problems that are important to them" (Krajcik & Blumenfeld, 2006, p. 317) but the crucial aspects of this approach are that students have to create an end product and that the end product seeks to solve problems (Helle et al., 2006). As with any approach to teaching and learning, there are variants in use, and PBL is no different. According to Morgan (1983), there are three models for project work. Helle et al. (2006), citing Morgan (1983), noted that two of the three models "tend to leave more scope for student centeredness" (p. 289). S. Bell (2010) asserted that students having options, the freedom to make decisions are central to a PBL approach.

Marg's comment "some students doing 3D design but others not doing it" (Marg, interview, 5 December 2017) suggests that the school's approach aligns with students having some autonomy in their projects, as Bell (2010) and Morgan (1983) described. Significant to this research study is that the autonomy relates to some students using technology to create a product, whereas other students take a non-digital approach. In other words, the approach seemed to stretch the teachers in that they had to provide "other kinds of help". According to Marg, this approach with only some of the students engaging in 3D design caused issues for

her and Faith in focusing on technology integration.

The contextual factors that are illustrated by Marg's struggles could be said to be at the classroom level as there were issues in the teachers having to attend to matters not related to technology. These seem to fit with the micro level described by Porras-Hernandez and Salinas-Amescua (2013). However, there are underlying considerations which point to context at a meso level, given that decisions had been made to have these classes take a team-taught PBL approach to teaching and learning. These decisions were not made by Marg and Faith, but more importantly, these decisions created a unique environment, a context that influenced how the teachers integrated technology. This can be seen through the principal's comments that "the context of those classes are very different", and part of that difference was "the type of teaching that is being done with team teaching" (Principal, interview, 11 December 2017). This clearly indicates that having a PBL approach that is team-taught with a specific "type of teaching" creates a situation that is different than other approaches involving individual teachers and/or where other, non-PBL approaches, are used. Hence, the outcomes of teachers integrating technology in their classrooms and how the SDLs influence teachers' knowledge and practice may be affected by such contextual factors. This has been shown, through what Marg described, as causing difficulties for the teachers to work with the SDLs, focus on 3D design and ultimately develop TPACK.

Returning directly to use of the TPACK lens, in terms of XK, Marg's views on the struggles in the classroom and her preferences for working more effectively with the SDLs correspond with the belief that XK is a type of knowledge needed by teachers to develop their TPACK (Mishra, 2019). Corresponding well with Faith's call more for a more structured approach to working with the SDLs (Section 6.3), this seems to support the notion that XK "is something that we (as teacher educators) can act on, change, and help teachers develop" (Mishra, 2019, p. 77). In other words, these kinds of contextual factors and the knowledge that teachers in Marg and Faith's position should have ought not to be left to the teachers themselves to decipher. Thus, it could be said that the introduction of the SDLs may have

been more effective in positively affecting teachers' TPACK if contextual factors relating to the teaching and learning of PBL were recognised. These could have then been discussed with the teachers and plans put in place which would have enabled more effective involvement of the teachers with the SDLs during in-class assistance.

To summarise this section, we have seen that, in a classroom, there are a number of contextual factors that need to be considered which clearly affect events and behaviours related to TPACK. In this case study, some of these factors were positive in that they created an environment where the SDLs were able to work with the PBL students with relative ease. However, to focus on the research question and teachers' knowledge and practice, contextual factors did not seem to aid the teachers in being able to improve their knowledge or their practice in respect of technology. There were factors at the micro level, particularly in respect of the teaching environment with an open learning space and students in different locations within that environment, demanding the teachers' attention. However, this seemed to be exacerbated by a meso-level contextual factor, namely having a PBL approach to teaching and learning. This enabled the students to be at different points in their problem-solving attempts, using different techniques. By not having all or the majority of the students using technology, the teachers seemed to be drawn away from that focus. This, in turn, seemed to dilute the time spent working with the SDLs and PBL students designing with the software, which had a knock-on effect with little development of the teachers' TPACK.

Mishra (2019) suggested that XK is "of critical importance to teachers, and a lack of it limits the effectiveness and success of any TPACK development, or a teacher's attempts at technology integration" (p. 77). This section concurs with his comments. Hence, "we should consider the holistic environment, taking into account more comprehensive sociotechnical issues for modelling and design" (Dolgopolovas & Jevsikova, 2020, p. 3). Realising this in terms of the introduction of the SDLs and the contexts in which this was put into practice would have led to more comprehensive preparation and an appreciation of the broader factors that could have affected the development of TPACK.

6.5. Conclusion to Case study 2

This case study featured Marg and Faith, both relative newcomers to the school and to PBL, working as a teaching team. For the most part, the case study shows that they struggled to gain the confidence and skills necessary to integrate technology successfully in their PBL class. The way that they worked with the SDLs and two of their peers, Paul and Roger, gave them opportunities to be influenced to improve their knowledge and practice teaching with technology. However, in both respects, this did not happen. This has led to these three main conclusions:

1. **Where SDLs are introduced to CoPs with teachers who have a wide range of skills, confidence and experience, the influences SDLs can have on teachers may be affected by factors unrelated to the SDLs. Issues such as legitimacy and peripherality in CoPs may affect any influence SDLs can have.**

The roles that Marg and Faith took on in this case study and the relationships they had with Paul and Roger align well with Wenger's (1998) description of old-timers and newcomers. This meant that Marg and Faith had opportunities for developing their TPACK and their practice related to integrating technology with assistance from more-experienced teachers. However, it was shown that, for this to happen, there needed to be development of a mentor/mentee relationship between the old-timers and newcomers, which did not occur.

Marg and Faith did not involve themselves in introducing 3D design software to the students in their PBL class, despite taking part in the software training session. Due to their self-confessed lack of confidence and skills with the technology, they arranged for Paul and Roger to teach the students from their class who opted to use the technology for their PBL projects. This introduction was led by Roger and the SDLs, but as it was in a different location, it effectively excluded Marg and Faith from any exposure to classroom practice involved in teaching their students at this early stage, thus limiting the development of a mentor/mentee relationship. Without that relationship development, Marg and Faith did not

really have conditions of peripherality and legitimacy in respect of technology integration, as Wenger (1998) described, as it largely prevented them from being on inbound trajectories to gaining fuller participation in a CoP.

This has implications for limiting any possible influences SDLs can have on teachers' knowledge and practice. When teachers limit their exposure to teaching with technology, the development in confidence and skills in this is also likely to be limited. Through such a lack of participation and the roles that their peers take teaching their students, the knock-on effects for SDLs being able to influence these teachers are limited. The suggestion here is that when SDL strategies are implemented with teachers lacking skills and confidence in integrating technology and teachers who are newcomers, there needs to be consideration as to how these teachers will develop in these areas and what the involvement of mentors and the SDLs will be.

2. **When SDLs provide in-class assistance, their role and the involvement of the teachers need to be considered. Both of these factors can affect mutual engagement, joint enterprise and a shared repertoire developing between the SDLs and the teachers.**

This case study described how Marg and Faith willingly involved the SDLs, having them provide in-class assistance during their PBL classes. The teachers were very complimentary of the SDLs in being able to support their students as well as the skills and knowledge they had. In addition, their comments suggest that the SDLs provided valuable support to the students using 3D design in their projects. However, the work of the SDLs was largely independent of the teachers. Marg and Faith had little involvement in the SDLs' work and had predominantly separate roles in the classroom.

Having SDLs in the classroom was intended to provide teachers with in-class support to integrate technology as well as support for students in learning how to use the technology. In other words, the involvement of the SDLs in this aspect of the research study was intended to

affect teachers' knowledge and practice in how to teach with technology, through teachers learning from and with the SDLs. In-class assistance was an opportunity for teachers to not only negotiate their role and that of the SDLs but also to observe and learn from and with the SDLs, thus developing aspects of their TPACK and practice. However, due to the separate roles that SDLs had during in-class assistance and the teachers' lack of involvement with them, these developments did not occur.

The implications of this are that SDL strategies need to be carefully thought out in respect of how teachers and the SDLs work together in a classroom situation. There need to be opportunities for teachers to work alongside SDLs and develop mutual engagement, joint enterprise and a shared repertoire around integrating technology. The SDL roles need to be organised so that the SDLs are not working too independently, which means knowledge and practice are developed in the teachers. How knowledge and practice are shared between the SDLs and the teachers needs to be considered.

3. **Where SDLs work with teachers struggling with confidence and skills in technology integration, planning and preparation time involving the SDLs prior to in-class assistance as well as continuity and familiarity may be factors in the degree of influence SDLs can have on teachers' knowledge and practice.**

It was clear throughout this case study that both Marg and Faith lacked confidence and did not perceive that they had developed skills in using the technology, despite being involved in the software training session with the SDLs. They commented on barriers they had to using the technology. Faith in particular offered considerable detail on past experiences that resurfaced, hindering her capacity to develop skills and confidence with 3D design software. This was discussed in terms of identity using a CoP lens.

As mentioned in the previous conclusion point, Marg and Faith had in-class assistance from the SDLs but they did not attend the pedagogical discussion session with the SDLs. Nor did they really have any time to plan or discuss with the SDLs expectations, roles and

anticipated events prior to the SDLs being involved in their PBL class. Their comments in respect of this highlight how this left them uncertain of how best to work with the SDLs in their classroom. Similarly, they were unclear as to the exact purpose of in-class assistance, not realising that there was the intention to have SDLs and teachers working together rather than independently.

The organisation of this research study provided opportunities for a number of SDLs to be involved. There was no allocation of specific SDLs to work with particular teachers. The SDLs' participation in various aspects of this research was largely based on what they volunteered to do, perceived they could do and whether they were available. This meant that there were different SDLs involved at different stages and with different teachers; thus, for example, particular SDLs delivered the software session, some of whom were involved in the pedagogy discussion session, but this also involved other SDLs. When it came to in-class assistance, this had some of the SDLs who had been involved previously but also other SDLs who had not. Hence, there was no real continuity of the same, familiar SDLs being involved with particular teachers. The teachers in this case study highlighted this as being an issue in respect of lack of relationships and knowledge of the SDLs' strengths. They provided comments which could be linked to problems with mutual accountability and negotiated enterprise between the teachers and the SDLs.

The implications of all this are threefold. Firstly, SDL strategies need to be organised to provide planning and preparation time for teachers and SDLs prior to in-class assistance, particularly where teachers are seen to be struggling with skill and confidence in using technology. The provision of a pedagogical discussion session may be a solution to this, but when teachers do not attend this session, considerations have to be made for what happens to ensure preparations are in place for teachers and SDLs to work together in a classroom effectively. Secondly, information needs to be shared with the teachers involved, to ensure that they are aware of the purpose of the SDLs at all stages. It cannot be assumed that teachers will work with SDLs in a classroom situation that is conducive to the development of

their own knowledge and practice in integrating technology. A better understanding of how teachers and SDLs should work together and what the intentions are could lead to better outcomes for the teachers in this situation. Thirdly, there may be some teachers who benefit from or need to have continuity in the SDLs they work with when there are multiple sessions involving SDLs and teachers. Having SDLs who are familiar to them, who they work with at different stages, may provide greater opportunities to develop mutual engagement and develop a joint enterprise. This can then lead to the SDLs being more effective at influencing teachers' knowledge and practice, particularly when providing in-class assistance.

4. **Contextual factors are significant when SDLs provide in-class assistance to teachers. These factors can positively and negatively influence both teaching and learning.**

In-class assistance was provided to Marg and Faith with the intention of supporting them to teach 3D design and to supporting learners using the technology in their projects. However, there were a number of unique contextual elements to the in-class assistance. These came from both meso and micro levels. Examples of meso-level contextual factors can be seen in the way a PBL approach was set up, where student autonomy was encouraged, with some students using technology to create a product and others taking a non-digital approach. They can also be seen in leadership decisions to have the PBL teaching teams deliver to the classes. Examples of micro-level contextual factors can be seen in the teaching environments Marg and Faith taught in. They worked in open teaching spaces where other classes, students and teachers were also present. They and their students were also used to collaborating with their peers, other teachers and invited guests during their project work.

Some of these meso- and micro-level factors seemed to enable the SDLs to more easily integrate into Marg and Faith's PBL class, but other factors seemed to provide a hindrance to the SDLs' capacity to provide in-class assistance. The teaching space was seen to contribute to behaviour management issues that the teachers had to deal with, and this limited their

involvement with the SDLs and with technology integration. Limitations to involvement were also seen to stem from the teachers having to focus on other areas other than use of the technology. As students had choices as to whether or not to use 3D software, the teaching demands were different throughout the class. However, all these factors also meant the SDLs were able to focus on small groups or individuals in the class and assist them with learning how to use the technology. As the students were accustomed to collaboration, the SDLs' approaches were largely welcomed, enabling working relationships between the students and the SDLs to develop more quickly than expected.

The implications of this are that contextual factors that enable SDLs to more easily integrate into classrooms working alongside teachers need to be considered. Giving teachers the chance to discuss and plan with the SDLs how they will, for example, use their teaching environment, the resources they have at a meso level, how the SDLs' provision of in-class assistance can affect or is affected by the teaching methodology being used, could enhance the possibility of teachers' knowledge and practice being influenced.

Chapter 7: Case study 3 – Tom & Emma

This case study features two teachers who both seem to develop elements of their TPACK and practice through working with the SDLs. This is despite some significant contrasts in the teachers' identities and completely different approaches to working with the SDLs. Both teachers showed they were willing to work with the SDLs during the research study, forming strong and open relationships with them. There is evidence that both teachers were mutually engaged, had a joint enterprise and a shared repertoire with the SDLs. To fully understand how Tom and Emma's identities were such that they were positively influenced by the SDLs, in other words how the introduction of SDLs influenced their knowledge and practice, alignment will be discussed. This will highlight the significance of Tom and Emma aligning themselves to the SDL concept, its purpose, how it represented values and culture in the school and how this contributed to the formation of their identity and learning from the SDLs. However, despite evidence that the SDLs were in a CoP with Tom and Emma, further information will be presented that the teachers maintained professional boundaries between themselves and the SDLs, which they did not consider could be overcome. With these boundaries in place, the idea that SDLs can be brokers is moot, and the complexities of such a role are considered.

The case study will commence with consideration of the data that shaped the identities of Tom and Emma. A CoP lens will be utilised, with a focus on modes of belonging and the significance of how the teachers aligned themselves to the culture of the school and the PBL practices proposed for the project they were teaching. Evidence will then be revealed that all the dimensions required for there to be a CoP that involved both SDLs and the teachers seemed to exist. However, on deeper analysis, the teachers refuted suggestions that such a CoP could exist and affirmed that boundaries to entering such a CoP existed for the SDLs, despite both teachers having worked well with the SDLs during the research study. Thus, the final part of this case study will consider the SDLs as brokers and discuss the implications such a role had for working with Tom and Emma.

7.1. How two teachers are positively influenced by SDLs

This section will describe two teachers who, despite having very different identities and taking different approaches to working with the SDLs, spent time with them and were positively influenced in terms of their TPACK. The main lens used in this section will be CoP. This will facilitate discussion on how the introduction of SDLs influenced Tom and Emma's knowledge and practice. It will consider the identities of both teachers and their perceptions of self-confidence and skills both in terms of using technology and working with the SDLs. Use of a CoP lens will also highlight evidence of the three dimensions of a CoP developing between the two teachers and the SDLs. With further analysis, the significance of alignment for the two teachers in this research study will be shown.

This section firstly brings together data that highlights Tom and Emma's identities at the outset of this research study. It positions them as individual teachers working in a team and details their perspectives on using technology and working with the SDLs as well as the related experience they had in these areas. With this deep insight on Tom and Emma as teachers in this research study, the use of a CoP lens enables discussions on observations made of their working with the SDLs. This is supported by analysis of how each teacher reflected on their involvement with the SDLs. Both observations and reflections will highlight how the dimensions of shared repertoire, joint enterprise and mutual engagement can be seen to have developed between each individual teacher and the SDLs. However, also within the observation notes and teacher reflections, it will be shown how the concept of alignment enabled the teachers to develop their knowledge and practice through working with the SDLs.

The identities of Tom and Emma

As described in Section 3.1. (The context of this case study; Teachers involved in the case studies), PBL was taught by teaching teams who worked together with another team in a PBL teaching group. These teams and groups planned and monitored the teaching of their PBL classes together. They assisted each other in the development of practice around the teaching

of projects. Tom and Emma had been working as a teaching team since the beginning of the year and had already completed three projects with their PBL class. Hence, it is assumed that they had formed a CoP for their teaching team and/or with their PBL teaching group. Their roles in these CoPs is less clear, however, as the notion of old-timer and newcomer involves more than just looking at how many years a CoP member has been in their profession or working at a particular place. Both these teachers had a range of teaching experience, with some similarities but also a number of contrasts in terms of their experiences with the SDLs, with technology, with PBL and at the school. They also had views on technology and views on working with the SDLs that in some respects aligned, but in other respects, they differed. All these factors contributed significantly to their identity as members of the CoPs around the teaching of PBL to their designated classes, their attempts at integrating technology in their practice and the way they worked with the SDLs as part of this research study.

As already alluded to, there is quite a diverse selection of data on demographic details, self-reported views in respect of technology and views after having worked with the SDLs. This data highlights contrasts between the two members of this teaching team. It provides a basis for their identities to enable discussions and points to be made, particularly when using a CoP lens. Given that this data is scattered throughout this thesis, a summary is provided below in Table 8. This consists of Tom and Emma's demographic details from Table 3, their self-reporting on technology and working with the SDLs from Table 4 and their views on the degree to which SDLs affected their knowledge and practice from Table 5.

Table 8: *Summary data on Tom and Emma*

Demographic details	Tom	Emma
Years teaching	6	20
Years teaching at the school	5	1
Experience of PBL	No	No
Involved in PBL planning	Yes	No
Joined PBL team	At start of 2017	At start of 2017
Self-reporting on technology and working with the SDLs		
Scale: 1 = *digital technology should be used as little as possible* to 5 = *I should maximise opportunities*		
Views on use of digital technology in teaching practice?	5	3
Confidence generally in using digital technology as part of teaching practice	4	2
High skill level generally in using digital technology as part of teaching practice	5	2
Previously been trained in use of digital technology by students	Yes	No
Previously had in-class assistance from SDLs	Yes	No
Views on use of digital technology in teaching practice?	5	3
Self-reported views on the SDLs affecting knowledge and practice		
Scale: + positive; = neutral;- negative		
Do you think your knowledge & practice have advanced in respect of this particular software as a result of being trained by the SDLs?	+	+
Do you think working with the SDLs has also more broadly affected your knowledge/skills/confidence in using technology in your teaching practice?	-	+

The demographic data on Tom and Emma in Table 8 highlights considerable disparities between the numbers of years each teacher had been in the profession. However, this needs to be contrasted with the number of years each teacher had been teaching at the school. Considering both of these data items, it is difficult to judge who was more experienced in terms of the CoPs around teaching PBL, particularly as neither teacher had prior experience of PBL and both had joined the team at the start of the year; but most importantly, , the focus is on a new CoP that could potentially develop between the teachers and the SDLs when working together.

Case study 1 featured relevant discussions on how Wenger (1998) described CoP members as either newcomers or old-timers. In these discussions, it was shown that such labels are unhelpful, particularly when there are numerous determinants of what amounts to experience.

Instead, what is more accurate is to recognise that CoP members are on a continuum of membership. Again, in this case study, instead of trying to label Tom and Emma as newcomers or old-timers, they can be seen as two teachers with a plethora of teaching experience, albeit experience at different levels. Their relative experiences contribute to their identities. These identities need to be analysed and discussed in terms of how they worked with the SDLs and how this affected their knowledge and practice when trying to integrate technology.

How the teachers viewed themselves in respect of using digital technology and working with SDLs in Table 8 clearly shows that Tom was more of an advocate for using digital technology in his practice and had greater confidence and skill level in using digital technology in his teaching than Emma. Self-confidence and skill levels contribute to teachers' ability to integrate technology, according to Ertmer and Ottenbreit-Leftwich (2010). This data also reveals that Tom had had experience working with the SDLs, having been trained by them on how to use particular software and having received in-class assistance, whereas Emma had not. The depiction of an old-timer sharing knowledge with newcomers as a result of having gained experience in a profession in Wenger (1998) highlights the value of such experience. Hence, we have a teaching team where there are clear contrasts in respect of self-efficacy and attitudes towards the use of technology in teaching.

The last two questions on knowledge, practice, skills and confidence in using technology from Table 8 provide an insight into how Tom and Emma judged the effect the SDLs had on attempts to integrate technology in their teaching practice after working with them in the research study. In other words, these questions are very much a self-evaluation of any impact the SDLs have had. Both teachers recognised that their knowledge and practice in respect of 3D design have advanced. However, there seem to be contrasts in their answers when the question referred to the broader use of technology in their teaching practice. For this question, Tom provided a negative response. When asked about this response in the reflective interviews, he explained that he already had some knowledge of how to use the software prior

to this research study: “I kind of had a grasp before and I think I still have a slightly better grasp than they did” (Tom, interview, 29 November 2017). In other words, Tom felt that he already had high levels of skill and confidence in using technology in his teaching practice, which can be seen in the data in Table 8. Working with the SDLs did not improve him in this regard, as he believed the skills and confidence in using technology he had were still greater than those of the SDLs.

The preceding paragraphs have provided data on Tom and Emma in areas relevant to integrating technology, to working with the SDLs and to their experience as teachers. From this data and the discussions, it can be deduced that this was a teaching team comprised of two teachers with considerable experience, albeit limited in PBL; Emma having less experience with PBL than Tom. As regards technology and working with the SDLs, there was far greater disparity between the two teachers; Tom having worked with the SDLs, expressing knowledge, confidence and skills in using technology in his practice.

Wenger (1998) stated that, “learning transforms our identities” (p. 227), and despite the differences in these two teachers, how they worked with the SDLs showed they were both willing participants in the research study to improve their teaching of 3D design in the PBL class they were responsible for. In other words, they positioned themselves as learners. Transformations in the teachers’ identities in this case study can be distilled as an analysis of changes in “who we are, our practices, and our communities” (p. 227). Thus, the next section will focus on factors of Tom and Emma’s identities, their practice when working with the SDLs and the concept of a CoP developing with the SDLs. This will largely feature evidence that shows that both teachers had open dialogue and fostered relationship development with the SDLs as well as the relevance of all this to their learning and ultimately to their practice.

Developing CoP dimensions with the SDLs

Emma missed the pedagogy session of this research study but wanted to follow up with the SDLs after having been involved in the software training session. Hence, it was arranged

for her to spend some time with one of the SDLs, discussing pedagogical approaches to teaching 3D design in the PBL class. Notes written while observing this session described the following:

> There seems to be an open atmosphere of sharing between teacher and [SDL name]. Teacher is open and honest about her own skills and knowledge when talking to [SDL name]. She shares lots of things about herself and also at one point about her class and the students in it. Teacher is talking about "the need to get my students to learn this". (Researcher observations, 25 September 2017)

The notes depict a scene where there was a rapport between the teacher and the SDL. Both parties seemed at ease with each other, and the teacher was willing to self-reflect, to express her needs in respect of integrating technology into her PBL class. Emma was asked about this observation and my interpretation. She said, "Yeah, I did feel really comfortable. I've always been really honest anyway and I really didn't know what I was doing, haha, until [SDL name] sat down and showed me how to use the software" (Emma, interview, 6 December 2017). Emma was clearly comfortable working with this SDL, even though the data in Table 8 depicts her as having no previous experience with students in SDL roles. She likened the open communication to her own personality traits, saying that she felt she needed assistance with the technology, which she felt the SDLs provided this in the session.

However, Emma went on to highlight that the issue in not knowing what she was doing did not relate to competency in being able to design in 3D or specifically in knowing how the software package worked. Instead, it related to the use of technology for teaching and learning in the PBL class: "What I was trying to work out is, now I have a bit of an idea of how 3D printing works, it's getting that to fit within what I'm teaching and to get the students to have a go at that sort of prototyping" (Emma, interview, 6 December 2017). She clearly understood the purpose of the session with the SDL and its importance in preparing her for the use of the technology by her and her students. The idea of understanding how technology works on a level that ensures it "fits within teaching" highlights Emma's intentions from the session and the value she saw in engaging with a SDL to advance her TPK.

Tom was also observed to have built up a relatively strong working relationship with the SDLs. He was asked about this and said:

> Yeah, well, as soon as you put a student in the position of mentor, you take them from a position of student to be someone who is going to help you to build on your professional practice, to help you do what you are doing. You automatically, well at least I do anyway, start to talk to them in a different way. Tom, interview, 29 November 2017)

This highlights that Tom saw the changing of role that a student goes through when they become a SDL, how they switch into a position that has the potential to influence a teacher's learning and, arguably, practice. This is not necessarily a change in the SDL as such; certainly, there is no evidence in this research study to prove this. Instead, it is recognition that Tom, as a teacher, treated the SDLs differently; it changed the way he communicated with them and what he considered their role in developing his practice.

The comment reveals Tom's perception of his own identity and how it related to the SDLs he worked with. It is clear that he saw the SDLs as being positioned to help him advance his practice. This suggests the there was a more equitable relationship between himself and the SDLs than he would normally have had with his students. It elevated the power of the SDLs. However, his comments and the use of the word "you", which is actually a reference to himself, also reveal that Tom still saw himself as being in control of the relationship. The SDLs' power was elevated, and the relationship became equitable because he took them to that position.

The power dynamic and relationship with SDLs that Tom described seem to closely resemble how old-timers welcome newcomers into a CoP. Old-timers have experience of practice in a CoP, which newcomers have to learn in order to establish their position. Being able to learn such practice comes from the working old-timers and learning from them (Wenger, 1998). Hence, the power and authority remain with the old-timers. They are the CoP members in control. Tom's comments reveal similar perceptions of how he saw himself working with the SDLs.

Tom's perceived identity led him to "talk to the SDLs in a different way", which suggests that somehow their ways of communicating were different; possibly terms, language and the topics of conversation changed. As Wenger (1998) described, the elements of a shared repertoire "gain their coherence not in and of themselves…but from the fact they belong to the community pursuing an enterprise" (p. 82). In this sense, Tom appeared to describe himself and the SDL developing a shared repertoire in order to pursue their enterprise – improvements in teaching technology to PBL students.

There are also strong links in Tom's comments to having a joint enterprise with the SDLs. He perceived the SDLs as in a position to help him do what he was doing. The SDLs had been trained to provide professional development, knowledge and support for teachers to improve their knowledge and better integrate technology in their practice. Tom interpreted their role as being there to help him in his practice. This appears on the surface to be aligned with both parties having negotiated their enterprise: the "result of a collective process of negotiation" (Wenger, 1998, p. 77). However, the next few paragraphs reveal that Tom had more of a fixed perception of the roles SDLs should take, again maintaining his power and control in relationships with them.

As with Emma, Tom's focus for the SDLs' roles was not essentially about how to use the technology. He did not refer to this at all, and in observations made of his interactions with SDLs prior to their in-class assistance, it was noted that Tom "tells SDLs what he wants them to do with students in next lesson" (Researcher observations, 14 November 2017). In other words, he had clear plans for how they were to be involved in his and Emma's PBL lesson, the role they were going to take in assisting students with 3D design. This, in turn, highlights how the SDLs were intentionally positioned to affect teacher practice, and as he was working with Emma in a teaching team, it is likely to similarly affect hers.

Tom's approach to the SDLs was more direct than Emma's. His explanation was "because when I go into a lesson, I know what I want to focus on" (Tom, interview, 29 November

2017). In contrast, Emma's approach to the SDLs was to build knowledge and confidence in how to teach with technology rather than being focused on the events of a lesson. Their approaches align well with the data that is presented in Table 8 and the subsequent discussions around that, as they highlighted that someone who had greater confidence, skill and experience with technology and had worked previously with SDLs, had the SDLs directly affecting his classroom practice, whereas Emma, who was not as confident, skilled or experienced, invested time with the SDLs in discussing approaches that would likely benefit her practice when trying to integrate technology.

Despite having different approaches to the SDLs, both Tom and Emma displayed many of the characteristics of what was required to form a CoP involving the SDLs. There was joint enterprise between the SDLs and both teachers. Tom reified the concept of in-class assistance to suit what he saw as the ideal role for the SDLs in his PBL class. He asked them, "Do you reckon if I gave you about half an hour, could you run a session with the kids on 3D design for about … erm … 20 kids?" (Tom, SDLs briefing session, 14 November 2017), to which they agreed. This reveals a certain mutual accountability to the PBL students receiving an introduction to the technology. Emma's approach reveals more of how Wenger (1998) described a negotiated enterprise. She worked with the SDLs to develop knowledge and practice for integrating technology to enable the students to build 3D design prototypes in the PBL class.

Both teachers displayed engagement in respect of learning how better to teach with the technology and engaging with the SDLs, particularly in how they invested time in developing relationships and share their practice with the SDLs. As Wenger (1998) stated, "being included in what matters is a requirement for being engaged in a community's practice just as engagement is what defines belonging" (p. 74). Tom and Emma both included the SDLs in what they were doing as teachers, albeit with different approaches for each teacher. The level at which they involved the SDLs was clearly significant to the development of their knowledge and practice around teaching 3D design.

Lastly, in respect of what was required to be recognised as a CoP, it is worth returning to the concept of shared repertoire. Tom's earlier comments suggest he perceived the SDLs as being in roles where they would have a shared repertoire. Emma actually demonstrated this repertoire during her interactions with the SDLs. She "create[d] resources for negotiating meaning" (Wenger, 1998, p. 82), sharing these with the SDLs. This involved Emma telling the SDL she worked closely with a story about her experiences at a large comic convention, which she explained as relating to "making a connection back to my world" (Emma, interview, 6 December 2017). The story clearly resonated with Emma and allowed her to connect what was being said to her by the SDL to something she had experienced. It highlights how concepts were being understood through the development of shared repertoire between the teacher and the SDLs.

Thus, to summarise this section and this case study, there is strong evidence that both teachers were showing the dimensions needed to develop a CoP with the SDLs. This is despite the different approaches each of the teachers were taking towards what working with the SDLs could offer them. Their skills, confidence and experiences were identity factors that contributed to how they worked with the SDLs and the relationships they developed with them, but they do not tell the whole story. There is more evidence relevant to the identities of the two teachers and how they develop relationships with the SDLs to examine, which fits with the concept of alignment that Wenger (1998) described. This is the focus of the next section.

The significance of alignment when working with SDLs

The concept of alignment was discussed in detail in Section 2.3. (Particpation and non-participation). In that section, it was shown that discussions on alignment are in respect of "a scope of action writ large, of coordinated enterprises on a large scale" (Wenger, 1998, p. 179). It is where considerations are made of how individuals show "expression of their belonging to the broader social system in which their industry operates" (Wenger, 1998, p.

179). This is likely to come from evidence of how Tom and Emma considered wider issues than those which came from working in a PBL teaching team or from working with the SDLs. In other words, the focus here is on evidence which connects the teachers to the thinking behind working with the SDLs, how it fits in the ethos of the school with the drive from leadership to promote student voice and students in active roles with teachers.

As Wenger (1998) stated, alignment "is a form of identification because it shapes the way we experience our own power and this contributes to defining our identity" (p. 196). Applying this to Tom and Emma, we are looking at situations where they were "combining allegiance and compliance" (p. 196) to the concept of the SDLs, to what students in SDL roles represent and to what working with the SDLs is trying to achieve. Through looking at alignment, the intention is to get a better understanding of the identities of both teachers, given that "alignment subtly becomes part of who we are" (p. 197). There will be a focus on evidence that shows how Tom and Emma aligned themselves to the SDL concept, embracing and trusting the judgements of the leaders in the school, leading to trust in the capacity of the SDLs to enhance their knowledge and practice.

Before examining evidence from Tom and Emma's comments, it is worth returning to the discussions in Section 3.1. (The context for this case study) about the goals of the school and how the SDLs fit with the direction led by the Site Improvement Plan to further develop a culture of student voice (Principal, personal communication, 2016). The significance of the SDLs can also be seen in the principal's comments after the research study:

> Twelve months ago, even though we had a big student voice focus at the school, you wouldn't have had teachers going to kids to ask for their assistance and stuff like that. I think now the shift is that teachers see that as normal. (Principal, interview, 11 December 2017)

She clearly recognised the part that SDLs played in contributing to the development of student voice and her thinking in respect of advancements in this area of the school. This was a potential area for Tom and Emma to align themselves to. However, there were, also, other

potential areas for alignment in this case study, such as in the foundations of PBL (e.g., advancing student-centred learning) or in the project being taught (e.g., upskilling students in entrepreneurship or in digital technologies), both of which were also described in Section 3.1. (The context for this case study).

Tom made several comments that show his alignment to working with the SDLs and to the intentions of the research study to have students actively involved in technology integration: "[I'm] willing to run with the trust of other teachers. Like, if you obviously trust the SDLs to do x, y, z, my trust levels are going to raise to meet those expectations" (Tom, interview, 29 November 2017). His reference to "you" in this comment was aimed at me, as a leader in the school as well as the researcher. Tom clearly showed that he was willing to act on decisions made by the school leaders and teachers, aligning his actions to trust the SDLs to perform certain roles in his PBL classroom. A very similar comment reiterated the notion of trust in the SDLs: "I just picked up on your perceived level of trust in them to be able to do it" (Tom, interview, 29 November 2017). This confirms what has already been discussed in respect of alignment but also highlights how trust was not questioned nor stated or directed. It was Tom's choice to "perceive" it and thus to align with the idea of working with the SDLs in this research study.

Alignment can also be seen to relate to previous experiences, to other elements that have contributed to Tom's identity: "We know what the expectation is here as we have done it a few times" (Tom, interview, 29 November 2017). He appeared to be drawing on his knowledge and experience of having worked with the SDLs. However, it could also be argued that he was aligning himself to the culture of the school – recent exponential growth in student voice and leadership opportunities driven by the senior leaders. Tom knew that there was a drive in the school to have students more involved in enhancing teaching and learning. His response could be interpreted as alignment to that drive.

We now turn the spotlight on to Emma. She suggested that she was aligned to the

fundamental aspects of the PBL project that the class had to learn and that she knew she had to teach them:

> Prototyping is really important for this project and the students need to be able to design prototypes and change them. What I was trying to work out is, now I have a bit of an idea of how 3D printing works, it's getting that to fit within what I'm teaching and to get the students to have a go at that sort of prototyping. (Emma, interview, 6 December 2017)

As detailed in Section 3.1. (The context for this case study), the theme of the project was invention, and the teachers led students through a design thinking process. A key aspect of this process was iterative design using prototypes and garnering feedback on them to aid improvement and refinement (Razzouk & Shute, 2012). Emma's comments clearly demonstrate that she recognised the need to focus on prototyping and how to use 3D design in creating prototypes. Thus, she seemed to align her requirements, and the issues she focused on, to the demands of what she saw as important points of learning for her to develop her practice in being able to integrate technology relevant to the project's theme.

In a similar way to how Tom related to previous experiences in his comments on alignment and how he showed he was aligned to the school's culture of advocating student voice, Emma did likewise: "We have had PD with students involved and it's important for us to hear their voice. So, I was thinking in terms of 'what is a learner gonna want from me?'" (Emma, interview, 6 December 2017). This highlights not only how Emma valued the input from students but also her wording and the use of the word "us" suggest that this was a value she saw as important for other teachers in the school, not just her. This seems to represent that she was aligned to promoting student voice, giving students the chance to impact how she approached her classroom practice.

To summarise the discussions on alignment in the last few paragraphs, Tom and Emma shoed alignment in various but quite similar guises through their reflective comments on working with the SDLs. These comments are significant, "because alignment concerns directing and controlling energy, it likewise concerns power" (Wenger, 1998, p. 180).

Recognising that alignment "concerns power" highlights that it "is a condition for the possibility of socially organized action" (p. 180). Thus, it facilitated both teachers in this teaching team in embracing the opportunity to work with the SDLs, developing relationships and ways of working that would enhance their practice and ultimately produce better learning experiences for the PBL students in their class.

Wenger (1998) talked about how alignment "creates a kind of community" (p. 182). He then went on to talk about how this "kind of community" is based on allegiance and "this kind of allegiance can galvanize energies in ways that create a strong community" (p. 182). Tom and Emma showed their allegiance to the PBL project, the culture of the school but more importantly to the concept of having the SDLs affect their practice. It is from this basis that alignment appears to offer an answer as to why both teachers developed relationships with SDLs and involved themselves in activities with the SDLs which would enhance their knowledge and practice.

Section 7.1 and the subsections within it have provided accounts of two teachers who, despite fundamental differences in their identities, formed strong working relationships with the SDLs. There is a continual thread running through Section 7.1, but particularly in the Developing CoP dimensions with the SDLs section, where it seems as if there is evidence suggesting that these working relationships amounted to a CoP having developed between the two teachers and the SDLs. This issue is discussed in the next section, where further comments by Tom and Emma will be analysed and the focus will be on boundaries for CoPs involving SDLs and teachers.

7.2. CoPs, their boundaries and SDLs as brokers

Section 5.1. (The formation and membership of CoPs with the SDLs) provided insight into two teachers working with SDLs, and questions were considered in that section as to whether a CoP developed between the SDLs and the teachers. Although there was clear potential for CoPs to be formed with SDLs, issues with trust and, in particular, with time, prevented any

potential becoming reality. This section will, similarly, look at whether a CoP developed between the SDLs and the teachers. Trust and time will be factors in the discussion. Further comments by both teachers reveal more intricate understanding of CoP boundaries and how these prevented the SDLs from having full access to the teachers' CoPs. With boundaries that prevent full access to CoPs, the issue of SDLs as brokers is considered. However, evidence also suggests that when brokering, the boundaries to CoPs are not necessarily fixed. They can shift, given certain circumstances, which can have an effect on the SDLs' role in a CoP.

At this point, it is important to return briefly to points already made about Tom and Emma having developed a strong relationship with the SDLs through working with them, albeit with different approaches, and as to whether a CoP formed between the SDLs and the two teachers. This sets the scene showing not only in terms of CoP dimensions described by Wenger (1998) but also in terms of the issue of trust and how this case study contrasts with what was argued by Paul and Roger in Case study 1.

CoP dimensions and trust

The formation of a CoP is reliant on there being three dimensions of practice in existence: mutual engagement, joint enterprise and a shared repertoire (Wenger, 1998). In Section 7.1. (Developing CoP dimensions with the SDLs), considerable evidence was produced that showed how Tom and Emma seemed to be working as part of a CoP with the SDLs. There were examples of all three dimensions of practice between the SDLs and the teachers. To consider this further, trust has been mentioned as a barrier to forming of a CoPs involving the SDLs in Case study 1; hence, it seems sensible to look for comments from Tom and Emma on whether this was a factor in this case study.

Both Tom and Emma stated that they trusted the SDLs to provide specialist knowledge and assist them in improving their practice. Referring to a SDL's ability to find resources that could help her, Emma said, "I had trust in him" (Emma, interview, 6 December 2017). She went on to describe how she "was relying on their expertise" and she "felt confident to rely

on their expertise" (Emma, interview, 6 December 2017). This not only provides a clear atmosphere of trust but also illustrates how dependent Emma was on their "expertise" and how convinced she was, they could fulfil the role she wanted them to. As shown in Section 7.1. (The significance of alignment when working with SDLs), Tom's trust came from aligning himself to the school practices and culture. He stated that he was "willing to run with the trust of other teachers" (Tom, interview, 29 November 2017) and trust the SDLs to be able to assist him in the classroom.

In regards to the issue of trusting the SDLs, there appears to be a contrast here with what Paul and Roger described in Case study 1. They talked about not being able to trust the SDLs fully to be able to provide them with what they considered necessary to enhance their practice, and that seemed to be a barrier to forming a CoP with the SDLs. Tom and Emma saw the opposite. This seems to provide further evidence to support the idea that a CoP was indeed developing between the SDLs, Tom and Emma. However, when the teachers were questioned specifically on this matter, it is clear that boundaries remained preventing the SDLs having full access to such a CoP. These boundaries are the focus of discussion in the next section.

CoP boundaries for SDLs

As Wenger (1998) explained, CoPs represent shared histories of learning, and as such, these "histories create discontinuities between those who have been participating and those who have not" (p. 103). A fuller explanation of boundaries was provided in Section 2.3. (Understanding the concept of practice), where it was highlighted that the elements of a boundary are specific to the particular CoP in question. In other words, there is a need to look at the factors for each CoP, as to what the boundaries are and how they prevent entry into a CoP. Hence, the teachers' comments will feature heavily in this section.

It was observed that Tom seemed to develop a strong working relationship with the SDLs, based on mutual engagement. He was clear on the role that he wanted them to take; in other

words, their joint enterprise and his dialogue with the SDLs indicated a shared repertoire. Tom was asked about these observations and whether the relationship was a CoP similar to those he had with his peers. His reply was:

> You still have a teacher/student relationship happening there as opposed to a collegial relationship which is different … Perhaps it's got to do with professionality in some ways. Once you have had a certain amount of contact with colleagues, adult colleagues, there is a level of informality that creeps into your practice, if that make sense. Whereas with students, you have to maintain that professional distance. (Tom, interview, 29 November 2017)

It is clear that Tom saw the relationship with the SDLs at a different level to those he had with fellow teachers. He stated that "professionality" was the difference between what he had with the SDLs and what he could have with teachers but then insinuated that time might be a factor. In other words, he still saw himself in a teacher/student relationship with the SDLs, which he considered was a more formal relationship. With continued development, this might become more informal. This relates to the comments made in Case study 1 regarding the time factor being a barrier to development of a CoP. There, it was argued that with more time, a CoP may develop between the teachers and SDLs, but enabling that was beyond the parameters of this research study. Thus, at the moment there is only potential, given more time.

Tom's last statement regarding "maintaining professional distance" casts doubt over whether a CoP involving teachers and SDLs, where the SDLs had the potential to take on centripetal role, would ever be able to occur. He seemed to espouse a need to keep the SDLs outside or on the periphery of the teaching community. This is supported by a later statement: "It's just about holding them at arm's length. You are trying to present to them the most professional example of what you are asking them to do" (Tom, interview, 29 November 2017). Here, it seems that Tom considered that the SDLs did not have the same professionalism as he had, and perhaps that is simply a recognition of his being a trained, professional educator whereas the SDLs were not.

Emma stated, “Ultimately I still have the responsibility for the class” (Emma, interview, 6 December 2017). Despite recognising the way SDLs had extended her knowledge and practice, her statement supports some of the professional distance Tom maintains was in existence between the teachers and SDLs. She also briefly mentioned the benefits she could foresee if there had been more time given to working with the SDLs, “a little bit, yeah, more time to get to know the SDLs” (Emma, interview, 6 December 2017), echoing views already offered about the potential to develop a stronger community involving the SDLs.

Further comments from Tom highlight how, despite the observations of a strong relationship with the SDLs, the way he talked to them and the expectations he had of them were, to his mind, different from those he would have had of a fellow teacher: “If I was talking to a colleague, I might not be so directive about it” (Tom, interview, 29 November 2017). From Tom’s perspective, he was giving structured directions of what he wanted the SDLs to do and he did not believe that this would be the same if he was working with another teacher providing the same assistance. His reasons for this were that he “wouldn’t want to step on teacher’s professional practice by assuming that they don’t know how to do that” (Tom, interview, 29 November 2017). This highlights how he saw a teacher being able to make their own professional decisions and choices, thus requiring less definite directions as to what to do in his lesson. In contrast, Tom felt that the SDLs needed such directions, which means they remained on the periphery of teaching practice.

Tom was then asked about his relationship with the SDLs and how it compared to those he has with the pre-service teachers. He was first asked whether there was a similar boundary to forming a CoP with pre-service teachers, to which he replied, “Well there is, yes. They definitely start similarly” (Tom, interview, 29 November 2017). He recognised how pre-service teachers, when first starting in a placement working with a teacher, face similar boundaries to participation as the SDLs face. However, by focusing on the start of the placement, there is a hint that there could developments in relationships with the SDLs. This could see SDLs having similar experiences to pre-service teachers, overcoming boundaries,

moving on inbound trajectories in a teacher CoP. However, the question remains as to whether this would ever be the same for the SDLs.

Looking at further comments from Tom, there seem to be answers as to whether CoPs could be formed with SDLs as they are with pre-service teachers. He talked about how, with pre-service teachers, "in that community, you are negotiating what those boundaries are going to be and how you are going to do your practice as a group. Over time, they relax, certain things become embedded, and they develop their own intimacy" (Tom, interview, 29 November 2017). This reveals a more in-depth insight as to the role that time has on developing a CoP than has previously been mentioned. In some ways, it seems to relate to structures or expectations that are in place when pre-service teachers join a school community. Boundaries are negotiated by the participants. As the pre-service teacher develops in the role, becomes more experienced, familiar with the school, the culture, the expectations and the students, their position in the CoP develop.

Tom's final remark on this issue seems to sum up his feelings on the differences between his relationship with the SDLs and those with teachers or pre-service teachers: "I suspect over time, you would develop a relationship with students as you would with any teachers but you I don't think you would ever develop the same level of professional intimacy as you would with teachers" (Tom, interview, 29 November 2017). This suggests that, despite seeing levels of mutual engagement, joint enterprise and a shared repertoire between Tom, Emma and the SDLs, there remain boundaries to the teachers' CoP that the SDLs could not and did not cross, regardless of the time factor. In other words, any CoP that could develop between the SDLs and the teachers would not be the same as those between teachers, regardless of the time spent developing such a relationship.

If it is recognised that there are insurmountable, or at least substantial, boundaries for the SDLs to participate fully in CoPs with teachers, the focus can shift to examine the role that SDLs did play, as it is clearly shown in this case study that they influenced both Tom and

Emma. A CoP lens can be used to look at what Wenger (1998) described as "the duality of boundary relations" (p. 104), where he highlighted how people "can participate in multiple communities of practice at once" (p. 105). This concept of multi-membership and how connections can be made between CoPs through the SDLs in brokering roles is the focus of the next section.

SDLs as brokers

Brokering is where there are "connections provided by people who can introduce elements of one practice into another" (Wenger, 1998, p. 105). The people in question in this case study were the SDLs. As discussed in Section 2.3. (Understanding the concept of practice), there was potential for the SDLs to share practices from one CoP to another as they worked with different teaching teams. This is a form of legitimate peripheral participation in the CoPs that teachers formed in their PBL teams and possibly in the PBL groups, as laid out in Figure 6. This section will look at the SDLs in the role of brokers, focusing on how they influenced Tom and Emma with what they had learned from working with other teachers. This will lead into discussions on the complexities that the role of a broker brings and how such a role demonstrates that the boundaries perceived to exist in CoPs may shift in certain circumstances.

Emma talked about the one-to-one session she had with a SDL:

> The conversation I had with her, erm, I guess was reassuring because she was able to say that it was all new for her too at one point but now after working with teachers, she understood the benefits of how it could work with students. (Emma, interview, 6 December 2017)

This highlights how the SDL made a connection for the teacher by sharing what she had experienced working with other teachers and how that changed her understanding. Given what has been discussed about Emma's struggles with confidence in using technology earlier in this case study, there is little surprise that she saw the SDL's comments as "reassuring" to her.

Further comments from Emma highlight how she viewed the SDLs not just as brokers in terms of boosting her confidence with using technology: “I saw the SDLs as technology specialists but also as student voice advocates” (Emma, interview, 6 December 2017). Although this does not specifically describe the SDLs as bringing practices from one CoP to another, it aligns with how Wenger (1998) describes the job of brokering: “It requires enough legitimacy to influence the development of practice, mobilize attention” (p. 109). Having specialist knowledge and skills with technology as well as developing student voice experience and skills, in Emma’s eyes, gave the SDLs legitimacy to influence her.

A conversation between Tom and the SDLs prior to the in-class assistance shows how the SDLs brokered ideas to improve prototyping opportunities and to affect pedagogy. In respect of prototyping, one of the SDLs suggested, “I can do Photoshop with them. That will be good for this project” (Tom, SDL briefing session, 14 November 2017). This is an idea that came from the SDLs. It was not prompted or suggested by the teacher in the conversation. The SDL’s suggestion shows that the SDL in question had ideas, understanding, possibly learning and experience in respect of prototyping and knew what software skills might enhance the students’ capacity in the PBL project. In other words, the SDL brokered his ideas to the teacher, which the teacher was then seen to agree to and facilitate in the session.

Right at the start of the first in-class assistance session for the SDLs with Tom and Emma, the SDLs suggested to Tom that they would be better standing in a certain place in the learning space (Researcher observations, 14 November 2017). Although this suggestion may appear quite trivial, Tom was asked about it in the reflective interviews and said, “It’s part of pedagogy” (Tom, interview, 29 November 2017). Given that it was a pedagogical suggestion made by the SDLs as to where to position themselves at the commencement of the session, this can again be aligned to the SDLs brokering ideas to the teachers, which potentially affected practice in the lesson.

To extend on the SDLs’ suggestion, Tom was asked about how this seemed to contradict

with his giving the SDLs structured directions on what he wanted them to do and how to do it, which were a focal point of the discussions in Section 7.2. (CoP boundaries for SDLs). He replied:

> It's good that those SDLs were able to talk about that. First of all, they have identified that they need to talk about something, they are able to throw that idea at me and unless if it was something I did feel strongly about then I'm fine with that. (Tom, interview, 29 November 2017)

This highlights Tom's willingness to be open to the SDLs' input, their ideas, their sharing of experience. It is an example of "alignment between perspectives" (Wenger, 1998, p. 109), which is one of the processes Wenger listed as making brokering complex. It is also more evidence that the SDLs had legitimacy with the teachers. It builds not only on what has been demonstrated in this case study but also in the first two case studies. There were many occurrences where the SDLs were able to "open new possibilities for meaning" (p. 109) for the teachers they have worked with in respect of technology integration.

However, there could also be the viewpoint that having the SDLs in a role where they brokered their own ideas was in fact a challenge to the boundaries that are purported by teachers to exist for SDLs. Tom was asked about how the first in-class session went with the SDLs and whether the SDLs had followed his directions or made their own decisions while working with the PBL students. He said, "It was pretty hairy and rushed but I do remember they came up to me afterwards and say something along the lines of we weren't able to do this or this didn't work so we did this instead" (Tom, interview, 29 November 2017). This illustrates how the SDLs, despite having been given specific instructions, might not necessarily follow these, especially when there were factors that put pressure on their ability to contribute fully as SDLs providing in-class assistance.

Tom added comments to the actions of the SDLs:

> They had tried something, and it didn't work so they used their initiative, and it was fine … they seemed to have done it relatively well … I let them do it their own way, yes. I

> wasn't directive about how they needed to run the session. (Tom, interview, 29 November 2017)

This highlights a completely different issue that the time factor can bring. Up to this point, time has been seen as a contributor to struggles with building relationships, trusting the SDLs and possibly forming CoPs with them. However, in this instance, being pressed for time seems to have prompted trust in the SDLs not to follow the teacher's structured directions. As seen in Section 7.2. (CoP boundaries for SDLs), the boundaries of a CoP which prevent the SDLs' full participation are, in some ways, related to trust. Subsequently, the teacher feels that they need to give structured directions in order for the SDLs to provide in-class assistance. However, there are instances, which can be related to time pressures, where the SDLs are able to provide in-class assistance in ways they deem appropriate. They are trusted, and as such, the boundaries to their participation in a CoP seems to shift albeit temporarily.

In summary, all of Section 7.2 has looked at two teachers who formed strong relationships with the SDLs, and through their interactions exhibited all three dimensions of what would be expected to be seen in a CoP. However, when examined closely and through responses to questions specifically about SDLs forming a CoP with teachers, it became clear that boundaries remained in place. These boundaries prevented the SDLs from participating fully in CoPs with the teachers and suggested that their role was more akin to brokering. Evidence showed the SDLs in brokering roles in this case study and how this could also be related to the roles they had taken in the first two case studies. However, it was shown that when brokering, the boundaries to participation in a CoP can shift for the SDLs. They can be trusted to work on their own initiative, giving them the capacity to affect practice in different ways or to a greater extent.

7.3. Conclusion to Case study 3

This case study described two teachers, Tom and Emma, working as PBL teaching team, who had very different approaches to working with the SDLs, yet developed strong working relationships with them. Evidence could be seen throughout the case study of the way teacher

knowledge and practice were positively influenced by the SDLs. The focus of the discussions was on the factors that enabled the relationships to develop between the teachers and the SDLs and any effects that the approach used in this research study had on those factors. This has led to these five main conclusions:

1. **A multifaceted approach to SDLs working with teachers provides numerous opportunities for teachers' knowledge and/or practice to be influenced. However, this requires teachers to be mutually engaged with the SDLs, intentional about their positionality and open and sharing in how they want them to be involved.**

This case study featured two teachers with very different levels of confidence, skills and experience in using digital technology in their teaching practice. In addition, one of them had previously worked with the SDLs, whereas the other had not. Thus, both teachers had different needs in terms of what the SDLs could offer them. This was reflected in the way that each teacher worked individually with the SDLs to improve either their knowledge or practice, accessing the SDLs at different stages to learn from and work with them.

Both Tom and Emma maximised the opportunities offered to engage with the SDLs, They purposely set aside time prior to the commencement of the class to learn and prepare for integrating 3D design into their PBL class. When working with the SDLs, they were open about their intentions, their own weaknesses, what they wanted SDLs to help them with and how best they saw the SDLs assisting them. This contributed to the development of strong working relationships with the, aiding the SDLs in being able to influence the teachers' knowledge and practice.

These findings have implications for how having teachers work with SDLs is planned and what it should offer, as they point to the benefits of giving teachers various opportunities to work with the SDLs in different ways. Recognising that teachers have different identities and experiences when integrating technology is, similarly, recognising that they will have

different needs in terms of assistance. However, even when teachers working with SDLs are provided optional sessions that offer opportunities to work together in different ways, the onus is still on the teacher to engage with the SDLs and approach the sessions with the right intentions. Their knowledge and practice will be influenced to a far greater extent by knowing what they want from the SDLs and creating an open, sharing environment that allows the SDLs to see how best they can work with the teachers.

2. **When teachers show an understanding of the role of SDLs, the reasons for SDL strategies being in place and how they reflect school culture, they can align themselves to the work of the SDLs, increasing the likelihood of their knowledge and practice being influenced by the SDLs.**

A CoP lens used in this case study enabled the process of identity formation and of learning for both Tom and Emma to be understood. Use of this lens revealed that both teachers had knowledge of the fundamental concepts involved in the PBL project they were to teach, the expectations of working with the SDLs and how the SDLs were part of the school culture of advocating student voice. They embraced all of these, aligning themselves to work with the SDLs.

The way Tom and Emma aligned themselves to working with the SDLs in this research study showed allegiance to the purpose of having the SDLs involved. This enabled them to develop stronger and more purposeful working relationships with the SDLs. By having those relationships, the SDLs were able to more easily influence the teachers' knowledge and practice as there was mutual understanding of the roles of everyone involved and the overall aims of the introduction of SDLs.

The implications of this conclusion are that the introduction of SDLs needs to be well thought out and planned for in a variety of ways. Firstly, consideration needs to be given as to how their introduction represents the culture of a school, particularly in respect of what student voice activities already exist and to what extent teachers have been involved in those.

Secondly, consideration needs to be given as to what information teachers should be given to be able to understand the purpose and role of the SDLs. This may involve teachers developing an understanding as to how they can best work with the SDLs and what the benefits will be to their own development as teachers trying to integrate technology. Lastly, careful consideration needs to be given to the authenticity of integrating technology. With an understanding of the meaningful involvement of technology that enhances learning, teachers are more likely to embrace the SDL concept.

3. **There is evidence of a correlation between the amount of time given to teachers to work with the SDLs and the degree of influence SDLs can have on teachers' knowledge and practice. An increase in one may lead to an increase in the other. However, teachers will always maintain barriers that the SDLs cannot overcome. Thus, the degree of influence the SDLs can have on teachers will always have limitations, regardless of time.**

Strong relationships that developed between the teachers and the SDLs featured heavily in this case study. The way Tom and Emma worked with the SDLs demonstrated many of the dimensions one would expect from members of a CoP working together. However, ultimately, it was shown through answers to specific questions in the reflective interviews that they saw barriers to being in a CoP with the SDLs. The way they saw the SDLs' roles indicated that SDLs remained on the periphery of the teacher CoPs of which they saw themselves as members. They also stated that they believed these barriers would always exist, as fundamentally, it is an issue of teacher professionalism and the fact that SDLs were students.

Despite recognising that barriers exist between the teachers and the SDLs, it was foreseen by the teachers that, given more time with the SDLs, relationships could be further developed. This indicates that the SDLs' positions working with teachers could be more centripetal, if only temporarily. This would provide more opportunities for the SDLs to have a greater

influence on teachers' knowledge and practice. However, as the barriers will always be there, the influence will be limited.

From this conclusion, there are implications for recognising that time is a factor in the development of relationships between the SDLs and teachers. With more time for teachers to work with the SDLs, establish and nurture understanding of roles and ways in which the SDLs can influence knowledge and practice, the SDLs will have a greater impact on teachers. However, when SDLs work with teachers, the establishment of CoPs where teachers regard SDLs as central participants, should not be expected. The SDLs will not be viewed by the teachers in the same way they view their peers or pre-service teachers, regardless of the time given over to working with them. This has further implications regarding the expectations of researchers, school leaders and teachers when SDLs are introduced.

4. **Having a strategy that enables the SDLs to broker their own ideas from experiences they have had in learning about technology and from working with teachers integrating technology can upskill them to influence all the teachers they work with.**

As this case study showed that there are barriers to creating CoPs between teachers and SDLs, the concept of brokering was used to analyse how the SDLs worked with Tom and Emma. This highlighted how the SDLs were able to contribute ideas that stemmed from their own experiences and learning when trying to use technology. These ideas described how the technology could be used by the students for the enhancement of their PBL projects and the pedagogical approaches they benefitted from when learning 3D design. Sharing these ideas added to the teachers' knowledge and practice, affecting confidence and understanding in integrating technology for Emma and, for Tom, directly affecting his practice when the SDLs provided in-class assistance.

There are implications for planning and implementing the involvement of SDLs with teachers. As regards planning, having SDLs exposed to teaching of technology, having SDLs

experience the approaches that a teacher used with them and providing SDLs with the chance to consider what they see as beneficial to their learning, enables them to share this information with the teachers they work with. Their learner perspective is a valuable asset for teachers to experience. Training SDLs, having them understand the roles they are going to take when working with SDLs and the sort of information teachers will find valuable can assist in this.

In respect of implementing a strategy involving SDLs working with teachers, thought should be given as to whether the scale and the logistics of the strategy enable the SDLs to broker practices and experiences from working with one teaching team to another or one teacher to another. Giving SDLs access to multiple opportunities to work with teachers and to work with different teachers will enable practice to be shared and them to learn from experiences, the outcomes of which they can share more widely.

5. **Implementing a strategy that involves SDLs providing in-class assistance requires some autonomy to be given to the SDLs and the recognition that they will need to use their own initiative when working with students at times.**

Tom's work with the SDLs during the in-class assistance phase of this research study featured heavily in this case study. He was shown to have organised brief discussions with the SDLs just prior to their involvement with the PBL class, planning logistics and directing their involvement. Tom provided a substantial amount of reflections on his interactions with the SDLs during these discussions and throughout this phase. Through some of the later reflections, it was revealed that, despite quite meticulous planning and clear directives being given to the SDLs, there were factors that meant the plans could not cover exactly how the SDLs were supposed to respond when providing assistance to the students.

Tom recognised that the SDLs used their own initiative after acknowledging that certain approaches they were using were not working and in response to time pressures. Tom's trust

in the SDLs to be able to assist the students and contribute to his practice in PBL lessons, meant they had a certain amount of autonomy to deal with the unplanned eventualities that often occur during teaching and learning.

This conclusion has implications for providing guidance and information to teachers as regards what to expect and how to respond when SDLs are providing in-class assistance. Teachers may want to provide highly structured information and definite roles for the SDLs working in their classrooms but, ultimately, there are possibilities that the plans may not work as intended. Thus, establishing relationships with and granting a certain amount of autonomy for SDLs to make decisions and respond to those they are assisting will enhance their effectiveness in classroom environments.

Chapter 8: Case study 4 – Finn

This case study focuses on just one of a teaching team comprising two teachers. The other teacher in the teaching team, Kay, attended only the software training session and did not complete the pre-involvement survey (see Figures 6 and 7). This meant, in accordance with the description in Section 3.1. (Teachers involved in the case studies), no follow-up reflective interview was organised with her. Finn, on the other hand, participated in the software training and pedagogical discussion sessions, returned the survey and volunteered for the reflective interview. The data and comments from all those sources will feature throughout this case study.

In this case study, the teacher will be shown working closely with the SDLs, particularly during the pedagogical discussion session. The discourse will centre on how distributed knowledge shared with SDLs can enable a teacher to improve TPK and TK in the TPACK framework. The knowledge acquired from working with the SDLs was used by a teacher planning for two different scenarios: working alongside the SDLs providing in-class assistance and teaching without in-class assistance from the SDLs. In both these scenarios, the SDLs provide valuable knowledge to improve teacher practice in integrating technology. Despite experiencing only one of the scenarios, teaching without in-class assistance, it will be shown how the teacher was influenced by the SDLs. This will lead on to a discussion of the literature on distributed TPACK and highlight how the findings in this case study challenge aspects of that literature.

However, before analysing evidence and discussing how the teacher and the SDL shared knowledge, an introduction to this case study is worthwhile to establish the identity of the featured teacher, Finn, and his more general reflections on working with the SDLs. This will provide useful information on Finn's perspectives on the pedagogical session with the SDLs in relation to the teachers who featured in the previous case studies. It will reveal not only how he was both mutually engaged and had a joint enterprise with the SDLs in trying to

improve his practice but also how he saw the effects the SDLs had on his peers. The next section will commence with that introduction.

8.1. Mutual engagement and joint enterprise with the SDLs

The data in Table 3 shows that Finn did not have a great deal of experience in the teaching profession, having been a teacher for only 4 years and joining the school at the start of the year. Prior to his involvement in teaching PBL, he had not used this approach in his practice but was involved in the planning for the PBL course. His demographic details are quite similar to those of Paul, discussed in Case study 1, with the only differences being Finn's involvement in the planning for PBL and the fact that he joined the PBL team a term earlier. In terms of his self-reported views on technology, Table 4 shows that he was very much an advocate for using as much technology as possible in his practice, he was confident in using digital technology as part of his teaching practice but he did not consider himself to be particularly skilled at this. Table 4 highlights Finn's enthusiasm for working with the SDLs and that he had had in-class assistance from them. Again, there are parallels with Paul's self-reported views but also in some respects with Paul's team-teaching partner, Roger and with Tom from Case study 3. This data offers an insight into the fact that this case study features a teacher who had limited experience in many relevant areas related to aspects of this research study. In other words, Finn was not necessarily a newcomer in CoPs around teaching PBL and any areas involving the SDLs but he was certainly not an old-timer either.

However, as in previous case studies, the important point is not Finn's position in the CoPs related to the teaching of PBL he was a member of. What is more important is establishing that the use of a CoP lens positioned him as a teacher learning in practice. This learning "changes his ability to engage in practice" (Wenger, 1998, p. 95), and he clearly saw the learning opportunities that working with the SDLs provided him: "I really enjoyed learning from them, having the SDLs run through the sessions" (Finn, interview, 8 December 2017). His comments focused not only on the fact that he worked with the SDLs but also their

role in running through, in other words, leading the sessions. Finn appreciated that he was "learning from" the SDLs and being influenced by them.

Finn affirmed that he saw the SDLs as leading the sessions and the learning but also reflected on the positivity of the experience not just for him but also for the other teachers around him:

> In terms of having a vibe towards learning something, having students lead something, teachers were a bit more enthusiastic about it than experiences I've had leading teachers through the same thing. I have had three sessions with the same software with my faculty and the vibe in the room was fairly positive but nowhere near that, although different group of teachers. It was a totally different vibe to those sessions (Finn, interview, 8 December 2017)

Finn's reference to the positive vibe points to mutual engagement with a sense of doing things together, being a community of learners. He judged the response of his peers during both the software training session and the pedagogical session led by the SDLs. He could see the greater impact the SDLs had had in comparison to similar, previous experiences. This greater impact seems to stem from there being something different about the SDLs leading teachers with teachers being "more enthusiastic" to learn from the SDLs than from a teacher.

When asked why there was a different vibe and why teachers were more enthusiastic than during the sessions he had run, Finn said:

> I guess there is probably a bit of excitement to supporting those [SDLs] through quite a high level process, training teachers. So, in terms of that, there is this sense of pride to go, "How great is this? I'm so proud of our students. I'm gonna really support these [SDLs] by engaging". And I think it's a really natural thing to do rather than something teachers choose to do because it's teachers. I think it's quite a natural thing that buzz. (Finn, interview, 8 December 2017)

The first thing worth mentioning about this comment is the way that Finn described the work of the SDLs as "a high level process". He acknowledged the significance of the SDLs' roles, particularly in respect of how they related to the enhancement of teachers' knowledge and, possibly, practice. His wording reveals that, despite using the word "training" to describe

what the SDLs were providing for the teachers, that is quite a simplistic term. According to Garavan (1997) and Masadeh (2012), words such as "training", "learning", "education" and "development" are often used interchangeably both in common language and in research. Garavan insisted that training "can be associated with 'learning by doing' whereas education is more synonymous with 'learning by thinking'; development involves learning thinking, doing and feeling" (p. 42). The SDLs were providing software training and following these up with pedagogical discussion sessions where there was sharing of ideas on how to approach teaching using technology. Hence, the strategy used in this research study does not seem to fit with Garavan's definition of training. It seems more aligned with either Garavan's definition of education or that of development.

However, the crux of this comment seems to be around pride and how teachers' pride in being trained by SDLs creates enthusiasm and engagement, manifesting in a swell of support for the SDLs. Again, using a CoP lens, Finn's comments depict scenes of mutual engagement with different facets of the school community, students and teachers coming together to share practice, as was seen in the previous case study. There is, however, also evidence in this comment of a joint enterprise between the teachers and the SDLs. As Wenger (1998) maintained, the enterprise of a CoP is indigenous, shaped by the participants with factors that are both in the control of the participants and some that are beyond their control. Thus, in defining enterprise, there has to be recognition that a participant's "position within a broader system and the pervasive influence of the institution that employs them" (p. 79), while at the same time appreciating that participants "respond…in ways that are not determined by the institution" (p. 79). As teachers, it is, perhaps, predictable that seeing students from their own school community in SDL roles will instil a sense of pride, even more so, given the publicised ethos of the school promoting a culture of student voice (Principal, personal communication, 2016).

It is important to recognise that the term described by Wenger (1998) is *joint enterprise*, and in the context of this research study, such an enterprise involved both the SDLs and the

teachers. As Finn stated, “I think I enjoyed it more than if I had just learnt it either by myself or by a teacher” (Finn, interview, 8 December 2017). Although the exact reasons for the enjoyment are not given, there is a definite sense of the SDLs providing an enjoyable experience, something more than the teachers could have experienced if they had learned in different ways. It seems that the “vibe towards learning something” (Finn, interview, 8 December 2017) was developed through both the actions of the SDLs and the reactions of the teachers – very much in line with how Wenger described a joint enterprise as a complex process.

Finn’s comments provide the SDLs with what he saw as influential, arguably pivotal roles. They were providing knowledge, experience, training and teaching. The SDLs’ interactions with the teachers, from his perspective, echo how a CoP “affords multiple and diverse opportunities for learning” (Wenger, 1998, p. 118). According to Wenger, such a range of opportunities exists because of the plethora of ways members can interact at the periphery or in more centripetal positions. Finn clearly saw that the SDLs had sufficient legitimacy to influence his practice, regardless of their relative positioning in the CoPs.

To summarise this section, Finn clearly viewed involvement with the SDLs as a positive experience. His use of words such as “enjoyed” and “excitement” reflect his mood after working with the SDLs. Additionally, his more in-depth comments highlight how he saw the SDLs and teachers working together, with conditions conducive to how Wenger (1998) described learning in a CoP. The next section will reveal the extent to which Finn recognised the influence on his knowledge in respect of integrating technology into his practice.

Knowledge-sharing with SDLs for in-class assistance

This section focuses on SDLs sharing knowledge with the teacher in this case study, Finn. The knowledge shared gives Finn ideas on the roles that the SDLs could provide and how those fit with the teachers’ practice during in-class assistance. It is intended to reveal not only how these comments provide TPK that enabled the teacher to consider approaches to teaching

technology he might not otherwise have considered but also how this offers new perspectives on both the concept of distributed knowledge in TPACK and the role of the SDLs in influencing teachers' knowledge and practice.

The sharing of knowledge between the SDLs and teachers or, as it is labelled in TPACK research, distributed knowledge, was discussed in depth in Section 2.1. (Knowledge development in TPACK). Distributed TPACK espouses the theory that all knowledge components in the TPACK framework do not need to be held by the teachers themselves. When integrating technology, some knowledge may come from other sources. Research papers analysed in that section provided evidence of where students had influenced teachers' knowledge and practice, although the contributing studies were in university settings or under laboratory conditions (Di Blas & Paolini, 2017; Di Blas, Paolini, et al., 2014; Jones et al., 2015; Nore et al., 2010). Furthermore, the review of that literature raised issues with the degree of shared knowledge that influenced practice and whether knowledge was actually shared with the teacher or whether it, in reality, remained with the SDLs. The latter of these issues was the main feature in Section 6.1. (Newcomers and distributed TPACK). In that case study, Marg and Faith, newcomers who struggled to some degree with integrating technology, had the SDLs share TK with them and assist students in their PBL class. However, the knowledge was shown to remain with the SDLs due to the lack of involvement of both teachers in the process of teaching with the technology. This conclusion was supported by evidence that both teachers in that case study were still struggling with technology integration, despite being involved in the research study working with the SDLs.

This section is intended to support the idea that distributed knowledge can influence a teachers' knowledge and practice. Finn's comments will illustrate how the SDLs shared their views with him on how to approach teaching with technology during in-class assistance. His reflections demonstrate how significant he viewed their insights, despite not proceeding to have them involved with the students in his PBL class. Discussions will focus on distributed knowledge in TPACK and highlight how research to date in this area has featured TK,

whereas there is clearly scope for having students influence teachers' knowledge and practice in respect of their TPK.

Observation notes made during the pedagogical discussion session showed that "[SDL name] proposes ideas, saying, 'this is how I think it is best done'. [Finn] seems to be accepting those" (Researcher observations, 1 November 2017). When asked to verify these observations, Finn said that what the SDLs had provided had been "useful" (Finn, interview, 8 December 2017). He was then asked to compare the usefulness of their comments with the same comments from his peers. His reply was "It was of the same value. The detail they were commenting on meant it was of the same value. It would have been just as useful had it come from any teacher" (Finn, interview, 8 December 2017). Hence, what is being shown here on quite a general level is that a teacher had his knowledge positively influenced by the SDLs, and in that teacher's opinion, the value of that knowledge was in no way undermined or of lesser quality because it came from a student in the role of a SDL. There is a suggestion that the ability and/or willingness of the SDLs to go into "detail" elevated the quality of the knowledge they provided, and this influenced Finn to be more receptive, but the crux of this insight is the enhancement of a teacher's knowledge through working with the SDLs.

Finn was probed further as to how exactly he had been influenced by the SDLs during the pedagogical discussion session. He was asked whether the SDLs' suggestions were specifically pedagogical in nature. He replied:

> They were good because they sought ways to use their strengths and have the teacher compliment their strengths with strengths they didn't have. For example, [SDL name] was commenting on if he was working with small groups of students and there were behaviours arising, then there would need to be a teacher there to deal with those situations for him. (Finn, interview, 8 December 2017)

The SDLs were providing an insight into the requirements and approaches a teacher needs to think about during the SDLs' in-class assistance. The comments are based on the SDLs' knowledge and experience accumulated during their training process' and those insights were being passed on to Finn. There are, however, two more areas of Finn's reply that are worth

highlighting: the way that the SDLs recognised strengths and weaknesses in their own role and the way their advice sought to position a teacher in their practice. These will be discussed in the next paragraph.

Finn appreciated that the SDLs could identify their own strengths and how best to use them but, at the same time, understand the teachers' strengths and how best to use them. Finn's comments show that there he valued the SDLs' suggestions because they understood the various factors involved in the SDLs providing in-class assistance. Finn's comments also suggest that SDLs had shared and were willing to share contextual knowledge regarding the behaviour of the students in the class and the issues that the SDLs and the PBL teacher would face. From identifying their strengths, the SDLs went on to offer advice to Finn that, in many ways, tells him what would need to happen, what their expectations of him were; in other words, the expected role of the teacher during in-class assistance, and positioning the teacher in a behaviour management role, should the need arise.

Finn commented further on what the SDLs suggested: "He was saying where there would need to be teacher assistance, and it was very interesting to know that" (Finn, interview, 8 December 2017). This affirms what has already been said in the previous paragraph but references the teacher's own knowledge and how he found it "interesting" to have been given that information. In other words, there is a suggestion that either he had not thought about that or, at the very least, it added to his knowledge of how to work with SDLs providing in-class assistance.

Evidence has been provided thus far to show where SDLs took on a role of influencing a teacher's pedagogical knowledge, sharing their knowledge of how to approach a teaching situation when technology is involved. This is clearly the sharing of knowledge between a student and a teacher, and in this case the distributed knowledge is TPK not just TK, which previous research papers (e.g., Di Blas, 2016a, 2016b; Di Blas, Fiore, et al., 2014; Di Blas, Paolini, et al., 2014) have featured. Consequently, the suggestion here is that there is

an extension to existing research on distributed TPACK. This will be discussed in more depth in Section 8.1. (Perspectives on distributed TPACK). This case study suggests that by implementing a strategy where students as SDLs are given insight into providing in-class assistance, they can gain knowledge on their own and into the teachers' roles when trying to integrate technology. This enables TPK to become distributed knowledge between them and the teachers, as well as TK that they may have but that the teachers do not.

There remains, however, a question mark over whether the description of events in this section can really be said to have influenced the teacher, Finn. To put this another way, questions could be asked: What proof is there that the SDLs suggestions on TPK influenced Finn? How is this case study dissimilar to that of Marg and Faith, where the notion of distributed knowledge was shown to be flawed both by the teachers' lack of involvement with the SDLs and by a lack of improvement in their technology skills, confidence and knowledge? Finn's comments in the next two paragraphs reveal the answers to those questions.

Finn talked about how the influence of the SDLs: "[They] impacted my thinking on how to do this. We could ask questions about their learning experiences. That was a huge benefit which you would usefully have hypothesise about" (Finn, interview, 8 December 2017). The SDLs provided perspectives that, by the definition of Garavan (1997) cited earlier, highlights the teacher was being educated by them. It could be argued that Finn was also in the early stages of development, given that he expressed how he felt about the quality of learning. In other words, he was not only thinking but also feeling – two of the three elements required for development (Garavan, 1997). Again, comparing this to getting similar information from a teacher, Finn talked about how that would be coming from a "secondary source as it's passed through a teacher" (Finn, interview, 8 December 2017). In other words, he recognised the worth of the SDLs' student perspective as learners as well as what they have experienced in training and teaching with the technology. This suggests that Finn thought that the SDLs offered both a teaching perspective and a learning perspective in

respect of the technology. Having both perspectives can only enrich TPK for a teacher.

In contrast to Marg and Faith, Finn clearly valued the learning experiences provided by the SDLs, whereas Marg and Faith did not prosper in respect of being able to integrate technology. He was involved with the SDLs, engaging in the pedagogical discussion sessions, as noted earlier in the researcher observations. He was asked whether his knowledge and practice had advanced in respect of 3D design as a result of being trained by the SDLs, to which he replied that he "knew more about teaching it as a result of being trained by them" (Finn, interview, 8 December 2017). Hence, distinctions can be seen between how Finn worked with the SDLs and benefitted from the sharing of knowledge in comparison with Marg and Faith. This highlights that distributed TPK can occur without evidence of its actually been put into practice; but there has to be proof that the teacher's knowledge has been influenced by the SDLs. That influence validates that the sharing actually occurred as opposed to the knowledge staying with the SDLs.

In the next section, the focus moves from discussion about events that did not evolve into practice when teachers worked with SDLs to those that did. This will demonstrate how the SDLs shared TK and TPK with Finn. He was then able to think about, plan, discuss with the SDLs and ultimately make decisions on how best to approach teaching 3D design to his PBL students without the SDLs providing in-class assistance. Finn provided reflections on the PBL lessons where he integrated technology and connected events with the knowledge the SDLs shared with him.

Knowledge-sharing with SDLs without in-class assistance

According to Di Blas (2016a), "teachers tend to count upon a quite sophisticated system of resources that include the students" (p. 72), when integrating technology in their practice. Seeing students, or in this research study students in the role of SDLs, as a resource positions them as knowledge providers who can assist a teacher in developing TPACK. This section provides evidence of this knowledge-sharing and how Finn put that knowledge into practice.

Finn was asked about not having had the SDLs provide in-class assistance and whether that had had any negative effects on his experiences of working with the SDLs when he actually came to teach the PBL class. He said, “It didn’t because we had thrown some ideas around with the SDLs which I was able to use” (Finn, interview, 8 December 2017). In many ways, this sets the scene for how Finn viewed the interactions during the pedagogical discussion session, which is further supported, as Finn later described it as “a really open dialogue between teachers and between teachers and students” (Finn, interview, 8 December 2017). Hence, the SDLs were part of a system of resources (Di Blas, 2016a), as were the other teachers present in those sessions, contributing to Finn’s TPACK. However, as the research question looks at how the SDLs influence not only knowledge but also practice, when Finn stated that he “was able to use” that knowledge, he was indicating that there were more than just ideas; the ideas morphed into actions.

To focus on the knowledge that was shared during the pedagogical discussion session, Finn described the following:

> When we were communicating with the SDLs about their experiences, they had some experience of working with a variety of formats, so sometimes they commented on instructing to a whole class and then to part of a class who needed to use that technology for their solution and then another part of the class that didn’t need to but just wanted to learn the skills. So, hearing that before jumping into using the technology with our classes, was pretty valuable because it was pretty raw, from the student’s perspective. (Finn, interview, 8 December 2017)

Firstly, the fact that Finn described this as “communicating with the SDLs” illustrates the discursive nature of the session, how teachers and the SDLs were sharing knowledge. This was not a session where the SDLs were providing instruction or presenting information. However, he also stated that the focus was the SDLs’ “experiences”. This is supported by observations made of that session: “SDLs giving examples of their work with other students” (Researcher observations, 1 November 2017). In other words, the SDLs made it clear that they had been involved with other students, trying to upskill them on how to use technology and had learned from these experiences, which they were sharing in the session.

Finn's comments seem to highlight how the discussion between the SDLs and the teachers were dominated by considerations of pedagogy. He referred to how the SDLs referenced their experiences, talking about different teaching scenarios for students' use of the technology and adjusting practice to deal with the logistics of group sizes. Seeing the value in this due to its being "pretty raw" seems to indicate how Finn appreciated the SDL's candidness. This adds further support to the idea that the SDLs offered a unique perspective, given the fact that they were students in the SDL role sharing knowledge with teachers as opposed to being fellow teachers or leaders sharing knowledge, as seen in the previous section. In that interview, Finn said that if the information had come from teachers instead of the SDLs, it would be from a "secondary source" (Finn, interview, 8 December 2017), suggesting it would somehow be diluted.

To sum up Finn's comments, it is clear that what is being seen here is a teacher who had enjoyed discussing pedagogical ideas related to integrating technology, in an environment where SDLs have shared their knowledge gained through their experiences. However, this section aims to show how this distributed knowledge emanating from the SDLs evolved into practice. What has been discussed to date concerns only SDLs influencing a teacher's knowledge. Hence, in the next few paragraphs, the focus will shift to the issue of teacher practice, as seen in Finn's reflections on trying to integrate technology in his PBL class.

Finn described the basic structure in his class: "So, the way we took on what the SDLs said, we essentially had two types of student groups, the ones that needed it for their solution and the ones that didn't" (Finn, interview, 8 December 2017). In this comment, we can see correlations between the pedagogical and logistical knowledge that Finn had previously described as the SDLs sharing. With use of the phrase "we took on what the SDLs said", there is evidence of a multi-step process involving knowledge moving from the SDLs to a teacher, with the teacher then acting on that knowledge and adjusting his practice accordingly. Through this process, both a teachers' knowledge and practice can be said to be influenced by the SDLs. However, the research question in this thesis relates to how that

influence happens. Answers to "how" for Finn seem to relate to his earlier comments on the SDLs' candidness, an environment of open sharing between the teachers and the SDLs, and the worth of their experiences having taught other students using the technology. Additionally, the answers could be seen to stem from the mutual engagement and joint enterprise that the SDLs and Finn were seen to share, which was discussed in Section 8.1. In other words, it could be argued that certain conditions were in place that enable distributed TPACK between the SDLs and the teachers to occur. Whether this would occur if these conditions were not in place requires further investigation that is beyond this research study.

Finn then went into more detail as to events in the PBL lesson, the approaches he and his teaching partner had used to integrate technology and the influence the knowledge shared by the SDLs had had on their teaching practice:

> Students needed instruction at different times so in terms of providing that teaching of how to use the technology, instead of teaching someone how to repair their gutters before their gutters fail, it was just doing it when they needed it ... So, the fact that the SDLs were able to skill us teachers up for that meant that we then had the skills to help the students along with that. (Finn, interview, 8 December 2017)

Here, Finn highlighted quite specific student requirements and the choice of whether to be proactive or reactive as a teacher. This could also be seen as a choice of whether to provide direct instruction to the students or to encourage a more constructivist learning environment where students are more active participants in their learning (McLoughlin & Lee, 2007), with the latter representing the decision made.

There is strong evidence in Finn's comments that the SDLs influenced him and possibly his teaching partner to make decisions on teaching approaches with their PBL class. This can be seen in the way he linked this directly to being skilled up by the SDLs, and how their influence enabled such an approach to be taken. What is not clear, however, is what specific aspects of the approach his reference to the SDLs being "able to skill us teachers up for that" referred to. This could be interpreted as the SDLs sharing knowledge that suggested teachers should expect differentiated needs among students at different times; in other words, a focus

on what to expect from learners. Alternatively, it could be interpreted as more of a suggestion of how best to approach teaching with the technology. For example, the SDLs might have shared knowledge from their experiences in teaching students the technology, where they suggested a more constructivist approach. To put this more succinctly, the content of the distributed knowledge between the SDLs and the teachers in this case study could have been a focus on learning or teaching, or indeed both. Which of these types of knowledge was shared does not detract from the overwhelming evidence that it influenced Finn's knowledge, which led to changes in his teaching practice. Hence, it could be said that in answering the research question, in respect of Finn, working with the SDLs can influence teachers' knowledge and practice through sharing of learning and/or teaching knowledge.

To summarise this section, the reflective comments of Finn have highlighted how knowledge shared with him in the pedagogical discussion sessions with the SDLs influenced his knowledge. With this knowledge source, he approached teaching with technology in his PBL class in a specific way. This seems to align really well with the concept of distributed TPACK, showcasing facets of knowledge held, not by the teacher but by the SDLs. However, there is a focus in research literature on TK being the knowledge that is often shared from students to teachers, whereas this case studies highlights the sharing of TPK. The next section will discuss these two points.

Perspectives on distributed TPACK

Citing Di Blas (2016a), Ismil (2020) discussed the significance of distributed TPACK in technology-enhanced learning, saying she showed, "that a teacher learning how to integrate new technology tools would learn from students just as the students would learn from the teacher" (p. 32). The SDLs in this research study were students from the school and, as such, can be assumed to have been in positions to learn from the teachers featured in these case studies, including Finn. Paradoxically, Finn communicated openly with the SDLs and gained knowledge from them that they shared from their experiences both as learners of 3D design

and in teaching to other students. This knowledge influenced his thinking, the approaches he might take depending on whether he had the SDLs provide in-class assistance or not, and ultimately his practice when integrating technology into a PBL class without their assistance. In other words, Finn learned from the SDLs as the SDLs would learn from him if they were students in his class. However, there are some fundamental differences with what Ismil (2020) and Di Blas (2016a) describe in their research and events that have been highlighted in this case study.

The distribution of knowledge from the SDLs to Finn in this case study has centred on approaches to teaching with technology, to approaches to pedagogy and to TPK. However, the focus in Di Blas (2016a, 2016b), Di Blas and Paolini (2017) and Ismil (2020) largely related to TK, particularly when it was the students sharing knowledge for the teachers to use. Jones et al. (2015) featured shared practice, where knowledge on approaches to teaching with technology were shared, but this differed in many respects from what can be seen in this case study. Firstly, the setting for that paper was a university, and the participants were teacher educators sharing practice with each other. Secondly, the approaches largely concerned the use of technology such as a learning management system to teach online to pre-service teachers. Despite espousing the benefits of distributing TPACK among teachers, the conclusions and recommendations from Jones et al. referred to enhancing the role of teacher educators, and much of the discussion considered issues with keeping abreast with TK due to rapid developments in technology.

In Di Blas (2016a), the research project had involvement from secondary school teachers with some data and a brief discussion on PK. However, the conclusions referred to TK as the type of knowledge shared from students to teachers. Their findings featured PK, as she stated in the conclusion that “a strong PK rather than TK is the pre-requisite to success” (p. 73), calling on teachers to be trained in project-management skills and approaches to using technology. There was, however, no suggestion that students could offer such training or that knowledge could be shared on these approaches.

Many of the points made in Di Blas (2016a) were echoed in Di Blas and Paolini (2017). Again, PK featured, where Di Blas and Paolini's findings were that "teachers seem not able to use external sources for improving their pedagogical approach" (p. 2314). The findings of this case study seem to challenge teachers' inability to use external sources, as the SDLs influenced pedagogical practice. However, it should be pointed out at this juncture that the focus with Finn is his TPK, not PK. TPK was not mentioned in either Di Blas (2016a) or Di Blas and Paolini. Only TK, CK and PK were. Their research seemed to remain at a less granular level than that used in this case study. However, given that Di Blas (2016a) and Di Blas and Paolini centred on approaches to teaching, and the strong correlation between PK and TPK, there is enough evidence here to suggest that discussions in this case study have highlighted how the SDLs can influence teachers' pedagogical approaches to teaching with technology.

In previous case studies in this research, there has been considerable evidence of knowledge being shared by the SDLs with teachers on TK; and that is understandable, given that one of the three elements of this study was software training. Knowledge shared by the SDLs with teachers on TK also featured in this case study at certain points. The discussions in this case study, however, have largely concerned how to teach with technology, the pedagogical approaches that can be used with students in a classroom. The closing question in Di Blas (2016a) on future directions for research into distributed TPACK asked whether CK and PK change as a result of changes in technology. Indeed, much of the research around distributed TPACK has been led by discussions on the complexities of knowledge, particularly TK (e.g., see Di Blas, 2016a, 2016b; Di Blas & Paolini, 2017; Jones et al., 2015; M. Phillips et al., 2017). This case study suggests that there are also complexities with TPK, but more importantly that a teacher's knowledge can be influenced by students as SDLs sharing knowledge as part of their working together.

8.2. Conclusion to Case study 4

This case study discussed Finn, one of the teachers in a teaching team who participated in the software training session and pedagogical discussion session but did not have the SDLs assist him in the PBL class he taught with his partner. Throughout the case study, there is evidence that Finn enjoyed learning from and with the SDLs. His reflections illustrated the way the SDLs influenced both his knowledge and practice. Analysis of those reflections reveal why the SDLs were able to influence him from both a CoP and TPACK perspective. This has led to the following conclusions:

1. **The influence that SDLs can have on teachers is dependent on joint enterprise, where the teachers' understandings and interpretations of school culture determine their responses to participating in the strategy.**

Finn provided his views on working with the SDLs in an environment that was conducive to learning from and with the SDLs – being open to discussion and recognising that the SDLs had both experience and knowledge to share with the teachers. He talked about the excitement that he saw in his peers and himself about working with the students in SDL roles. He recognised that the mood that existed around working with the teachers contributed to the learning experience for the teachers involved.

As in previous case studies, there was evidence of mutual engagement between Finn and the SDLs, but this case study highlighted the significance of joint enterprise. Finn's reflective comments show that both he and his peers had an understanding that working with the SDLs was part of a broader enterprise in empowering students as well as a means to enhance their knowledge about integrating technology into their teaching practice. He saw the SDLs as having legitimacy to affect his practice and those of teacher CoPs he was part of. These factors created a positive atmosphere, positioned the SDLs where they could work with the teachers to negotiate their enterprise during the research study and gain an understanding of what aspects of practice each participant is accountable for.

These findings have implications for understanding how the introduction of SDLs fits in with school culture and how much teachers in a school community recognise that having students involved in such roles enhances directions such as student voice that a school is trying to promote. From gaining such understanding, the concept of working with SDLs can more easily be accepted by teachers. This leads to a positive interpretation of the learning experience, which is more likely to result in greater influence on knowledge and practice.

2. **SDLs can influence teachers' TPK, and this can be evidenced through a teacher being able to articulate what they have learned as well as well as demonstrating this in classroom practice. However, in order to influence teachers' TPK, the SDLs need to have experience in and knowledge of teaching with technology, not just learning with the technology.**

A TPACK lens was used in this case study to look at how Finn's knowledge was influenced by the SDLs, given two different circumstances. The first of these, where the SDLs would be present to provide in-class assistance, looked at the discussions Finn had with the SDLs on approaches to teaching with technology, given they would be working alongside him and his teaching partner in the classroom. As the SDLs did not provide in-class assistance for this teaching team, ultimately, the goal was to ascertain whether the knowledge the SDLs provided could influence a teacher, particularly where there was no evidence that the knowledge led to classroom practice. The second of these was for the teacher to try to integrate technology into their practice without the SDLs providing in-class assistance. Here, the goal was to see whether events in the classroom were influenced by the knowledge shared by the SDLs; in other words, whether the knowledge the SDLs provided influenced Finn to change his practice.

Finn's comments show that he valued the SDLs' insights into what roles and approaches he should take with their assisting in the classroom. Their suggestions outlined logistics and pointed out what to expect and how situations could be managed to maximise their

involvement and the teaching with technology. His comments also show that he gained knowledge from them and they influenced his thinking, despite not having had the opportunity to put that knowledge into practice during this research study.

Finn's reflections on how he approached teaching the PBL class without in-class assistance from the SDLs also show that the knowledge the SDLs shared influenced him. However, this time the influence could be seen on both knowledge and practice. He was able to articulate quite precise strategies and approaches he used in his class with students, which the SDLs had provided knowledge on, explaining not only what occurred but also how it related to the teaching and learning of technology the SDLs had described.

All of this has implications for what SDLs can be used for and the roles that they can take. Although one of the cornerstones of this research study is the active involvement of students in SDL roles where they have the opportunity to influence the capacity of a teacher to integrate of technology, that active involvement may be influential just by the SDLs sharing pedagogical knowledge with a teacher. It does not necessarily have to involve SDLs being in classrooms for a teacher to be influenced by them. To influence knowledge, pedagogical discussion sessions where teachers and SDLs share knowledge may be sufficient to influence a teacher's knowledge which they do not actually get to put into practice. Acquiring such knowledge on how to integrate technology in different circumstances could improve pedagogy and, in particular, TPK, influenced by the SDLs. Alternatively, there may be opportunities to put the same shared knowledge into practice. This suggests that SDL strategies are enhanced by planning for diverse scenarios and having the SDLs share knowledge of approaches to integrating technology in different scenarios.

However, it was clear throughout this case study, and indeed in other parts of this thesis, that the SDLs had experience and knowledge of how to teach with technology. How the SDLs were organised to work with teachers was described in Section 3.1. (The context for this case study): the SDLs were not only taught how to use the 3D software but also given

opportunities to teach it to other students. Thus, the SDLs were able to offer Finn perspectives on learning the technology but also on teaching it. The implications here are that the SDLs' capacity to influence teachers' knowledge and practice was significantly increased by their having been both teachers and learners of the technology in question. Thus, opportunities should be sought in developing SDL strategies before commencing working with the teachers.

3. **When the involvement of SDLs is set up to facilitate pedagogical discussion and knowledge-sharing between them and teachers, this can lead to teachers' TPK being influenced. This highlights the significance of TPK for teachers trying to successfully integrate technology into their practice**

This case study featured detailed reflections from a teacher on discussions he had with the SDLs about approaches to teaching with technology, the effects of working with the SDLs on himself and his peers, as well as the ideas he put to use in his classroom after working with the SDLs. There is considerable evidence throughout the case study of how much Finn valued the SDLs' insights into learning and teaching the technology. He was able to discuss openly with them and listen to their thoughts and experiences from their work as SDLs with the same technology they were training him and his peers on.

As already talked about, Finn's comments articulate that the SDLs influenced both his knowledge and practice in the classroom when trying to integrate technology. However, the emphasis here has to be on knowledge of and practice in how to teach with technology, in other words, pedagogical approaches. Using the TPACK label, TPK, this type of knowledge dominated Finn's reflections on working with the SDLs, and it is clear that approaches to working with the students in his PBL classes were influenced by the knowledge shared by the SDLs.

Hence, there are implications for developing SDL strategies so as to facilitate pedagogical discussions and knowledge-sharing between teachers and SDLs. Knowledge and practice

regarding how to approach teaching with technology can be seen to be enhanced when teachers have the opportunity to consider classroom practices, strategies and context. Having SDLs share knowledge and experience they have acquired in these areas can lead teachers to change their practice, which in turn elevates the significance of TPK for teachers trying to integrate technology.

4. **SDLs can share valuable knowledge with teachers. This supports the concept of distributed TPACK recognised in research but extends on that research as TPK is seen to be provided by the SDLs for teachers, rather than just TK.**

Distributed TPACK dominated this case study, and the relationships developed between Finn and the SDLs he worked with, saw an open sharing of knowledge. This is despite the SDLs providing in-class assistance to Finn. Finn was observed considering how best to approach teaching the PBL students in his class by seeking the opinions of the SDLs on his proposed ideas. Through consultation with the SDLs, Finn came to decisions on specific elements of his approach to the upcoming class in respect of integrating technology. These decisions were then implemented when he taught his PBL class.

The SDLs provided insights and guidance gained through experiences as both learners and as teachers of other students prior to involvement in this research. Finn was of the opinion that the type of knowledge the SDLs provided could be said to be, in many ways, different to similar knowledge shared from other teachers, professional trainers or leaders. He pointed to the value of their first-hand experiences. Finn suggested alternative knowledge providers would not be as valuable or offer the same insight. In other words, the SDLs offered a unique perspective on TK and TPK.

Hence, what was witnessed in this case study seems to align with distributed TPACK research that knowledge can be shared and that teachers can rely on aspects of knowledge held by those they interact with. Furthermore, it also aligns with scenarios described in papers such as those by Di Blas, Paolini, et al. (2014) and Di Blas (2014) and the discussions

provided in Section 2.1. (Knowledge development in TPACK), where students can be the providers of knowledge. They may have knowledge that is shared with teachers to enhance their ability to integrate technology into their practice.

However, this case study also seems to contradict what was found in Di Blas and Paolini (2017) regarding distributed knowledge not occurring in respect of pedagogy. At the same time, it also extends the theme of most of the research on distributed TPACK, which focused on sharing of TK to sharing of TPK. Given that Finn sought guidance on how to best approach the teaching of software to the PBL class in the pedagogical session and then confirmed the usefulness of that when he actually taught students, the focus here is clearly TPK. This case study shows how SDLs can share knowledge with teachers beyond TK. They can offer TPK as well. Distributed TPACK can include PK.

Chapter 9: Discussion

This research study focused on teachers' knowledge and practice and the role of school students in SDL roles in technology integration. A case study approach with four cases has been used to answer one central research question: How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders? This chapter brings together the findings and explores the implications. It provides insight relating to practice, research and theory. There are seven main discussion points and the order of these is not indicative of their importance. Instead, the structure is intended to provide a logical flow. This starts with a focus on peripheral positions from which SDLs operate, which links well with the second discussion point on brokering and CoP boundaries. However, the first two points are centred on SDLs influencing teacher practices, rather than knowledge. The third discussion point shifts the focus to knowledge and the significance of distributed knowledge. This then flows into a discussion on the role that teachers' identities play in determining how effective SDLs can be. The fourth and fifth discussion points consider other factors that were seen to influence how the SDLs influenced teachers' knowledge and practice, looking at team-teaching structures andthe issue of time. Lastly, the significance of contextual and organisational aspects, such as school culture and student voice are discussed in relation to contextual knowledge (XK) depicted in Mishra's (2019) TPACK diagram (Figure 2).

9.1. The SDLs' influence on teachers from peripheral positions

This research positions students in SDL roles, working with teachers attempting to integrate technology into their practice. As discussed in Section 2.3. (Defining a CoP), the relationships, harmonies and disharmonies that arise when SDLs and teachers work and learn together can be viewed through a CoP lens. Using such a lens enables an examination of the relationships and dimensions of practice of CoPs where teachers and SDLs work together. How these dimensions (mutual engagement, joint enterprise and shared repertoire) can lead to

SDLs being in positions to influence teachers can then be discussed.

SDLs face CoP barriers to accessing more centripetal positions in teacher CoPs. They spend most of their time in peripheral positions. With barriers in place, this has an effect on how they influence teachers' knowledge and practice. This section, in many ways, sets the scene for understanding how the SDLs are viewed by the teachers and how they are positioned to influence knowledge and practice from peripheral positions. Being in CoP peripheral positions provides SDLs with "various forms of casual but legitimate access to teacher's practice" (Wenger, 1998, p. 199). As to when, how that happens are the focal points of this discussion. However, in order to get to these foci, a description and analysis of CoPs involving the PBL teachers in four case studies follow. The analysis then looks at how teachers respond to the introduction of SDLs to their CoPs and the extent to which barriers for SDLs relate to trust issues and joint enterprise, resulting in SDLs remaining on the periphery.

This section commences with the drawing together of evidence from the case studies showing that CoPs seemed to have existed between the teachers. Firstly, the way the CoPs were set up by the school's deputy principal is described. This shows that there were conditions put in place that enabled teachers to mutually engage in an enterprise around preparing to teach PBL classes. Secondly, examples of how teachers in the study actually engaged, exhibiting CoP dimensions of practice when working together, are provided. These provide evidence of teachers working together as members of CoPs around the teaching of PBL. The discussion then moves on to focus on the involvement of the SDLs. They worked with the PBL teaching groups and teams in Term 4 of the school year. Evidence shows that, for the most part, this was an experience the teachers valued. In addition, many examples of dimensions of practice in a CoP were observed, with the teachers and SDLs seeming to share a joint enterprise, mutual engagement and a shared repertoire at various points during the research. However, despite seeing numerous examples of CoP dimensions of practice, suggesting teachers and SDLs can form a community, the SDLs were largely peripheral participants. The discussions in this section then look at what implications all of the evidence

has for answering the research question *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?*

In order to understand the conditions that were put in place so that the PBL teachers at the school had the potential to develop a CoP, the next two paragraphs provide a summary of the way teachers were organised to teach PBL. The structures and planning involved, alongside the evidence of what occurred when teachers spent time working together on the joint enterprise, show that CoPs developed between these teachers.

Conditions for the development of CoPs between the PBL teachers stemmed from planning by the senior leaders in the school. The planning meant the teachers were organised into PBL teaching groups of four, from which two PBL teaching pairs prepared resources and strategies for teaching for a year prior to team teaching when the course began (Figure 6). The PBL and the team-teaching approach featured in this research study were relatively new to the school. In the year prior to its commencement, the deputy principal "consciously paired" teachers and initiated regular professional development sessions for those involved (Deputy principal, interview, 8 December 2017). The PBL teachers worked together during that year, both in the organised sessions and in their own time, preparing themselves for the implementation of the course. At this stage, there was no involvement of SDLs.

The teachers continued to work together after the course commenced. During Terms 1 to 3, they taught in teams in PBL classes, conducted further planning, attended professional development and assessed students in their teams and within their PBL groups. Although not observed in this research study, the PBL teachers were provided with opportunities to develop relationships with their peers. They were given time to work on a joint enterprise and foster engagement related to being proficient in teaching PBL through targeted professional development sessions, teaching teams and group structures. According to Wenger (1998), "a community of practice is where people help each other" (p. 76); hence, these preparations for PBL were intended to enable teachers to help and support each other. These ways of working

seemed to provide favourable conditions for the development of characteristics of mutual engagement and joint enterprise, outlined in Table 2. However, there is no substantial evidence that CoPs actually manifested between the teachers just from the conditions and planning described. Discussions in the next chapter show where this occurred.

During this study, the development of dimensions of practice can be seen clearly through collaborations between Marg, Faith, Paul and Roger, both within their teaching teams and in their groups. Teachers in both teams decided on the roles they would take, negotiating their enterprise. Decisions were taken in the teaching group for Paul and Roger to provide support for Marg and Faith by introducing technology to students from their class. This further demonstrates negotiation of enterprise. It also highlights how these teachers were mutually engaged in trying to teach PBL. Throughout the case studies, there are examples of sharing in teachers' actions, in language and approaches to practice within the teaching teams, which highlights the existence of a shared repertoire, the third dimension of a CoP (Wenger, 1998). Lastly, the case studies provide substantial discussions on teachers' identities and how their trajectories affected their practice in PBL teaching teams and in groups. Thus, all in all, there is sufficient evidence to assume that there were CoPs developed between teachers in the PBL teaching teams and in the PBL teaching groups prior to the involvement of the SDLs.

Turning attention to the involvement of SDLs, there was largely consensus among the teachers that involving the SDLs in technology integration was a positive experience. All teachers talked about being able to form relationships that set up conditions for learning from the SDLs. All teachers spoke positively about having the SDLs involved, for example, "I found it very easy to learn from the SDLs" (Faith, interview, 5 December 2017); the way teachers and SDLs and teachers interacted was "a really open dialogue" (Finn, interview, 8 December 2017). Faith's comments highlight how the SDLs' knowledge and insight in respect of integrating technology was helpful for the teachers involved. Finn's comments point to how the teachers valued the way the SDLs were organised to work with them, enabling "open dialogue". Many other positive teacher comments and observation notes give

similar views of positivity towards working with SDLs.

Using a CoP lens to examine the teachers' comments about working with the SDLs and related observation notes highlights how CoP dimensions of practice developed when they worked together. An example can be seen in the pedagogical discussion sessions regarding how best to group the PBL students, where Paul and Roger listened to suggestions from the SDLs and asked their views. This demonstrates that the teachers and the SDLs were mutually engaged and working towards a joint enterprise in gauging the best approach to integrating technology into their PBL classroom practice. It also showed that the SDLs had a shared repertoire around the organisation of students when teaching with technology.

Subsequent classroom observations reveal that the SDLs' advice had been followed, which Roger confirmed when interviewed. Section 7.1. (Developing CoP dimensions with the SDLs) highlighted how Tom reified the role of the SDLs during in-class assistance. He was mutually engaged in discussions with the SDLs as to the logistics of how best to approach the classroom activities they were to be involved in. Both the teachers and SDLs were seen to agree to a plan of action for their mutual engagement in providing in-class assistance. In Section 7.2. (CoP dimensions and trust), Emma talked about "relying on SDLs expertise to help the students" and being "confident to rely on their expertise" (Emma, interview, 6 December 2017). This saw Emma mutually agreeing to the appropriate roles for the SDLs providing software demonstrations and assisting with use of the technology in her classroom. Finn observed how the PBL teachers working with SDLs in the two large group sessions was a "totally different vibe" (Finn, interview, 8 December 2017) than similar professional learning provided by teachers. He saw the way teachers and the SDLs were mutually engaged in learning how to use the technology and how to best to approach its integration into their teaching practice. This can be seen when Finn cites the example of a SDL and the teachers discussing how a teacher would need to be present to deal with any behaviour issues when the SDLs were providing in-class assistance. As for Marg and Faith, there was evidence of some mutual engagement and sharing of an enterprise with the SDLs, but not to the same extent as

the other teachers. The reasons behind this will be featured in a later discussion point.

To summarise what has been discussed in this section thus far: The PBL teachers developed CoPs around their teaching teams and groups. The SDLs were introduced to work with these teachers. Their work with teachers around the integration of technology into classroom practice revealed elements of what would typically be seen if a CoP were developing between the two groups. This could be in the form of a new CoP involving the teachers and the SDLs or the SDLs joining the existing PBL teacher CoPs. However, continued analysis of evidence in the case studies revealed that new CoPs involving teachers and SDLs did not, in fact, develop. Similarly, it shows how SDLs were, for the most part, kept in peripheral participations in existing PBL teacher CoPs and granted access only to more centripetal positions in certain circumstances. The thread of the next few paragraphs describes how trust issues related to joint enterprise created barriers that prevented the formation of any new CoPs and kept the SDLs largely in peripheral positions in the existing CoPs.

Analysis of the case studies revealed that, repeatedly, teachers highlighted barriers that were erected for the SDLs stemming from the issue of trusting them. Paul and Roger as well as Tom and Finn indicated that issues around trusting and forming relationships with the SDLs stem from the roles that teachers typically have, their professional conduct, the expectations of them and their professionalism. These factors position teachers and students in roles that prevent the formation of a CoP. Teachers' views on their roles and those of the SDLs prevent them from allowing students to have mutuality. The teachers did not trust the SDLs to have the same joint enterprise as they have as professional teachers. Although there was a shared repertoire, mutual engagement and joint enterprise around technology integration, the teachers did not feel the SDLs could have the same mutuality in respect of other classroom responsibilities that the teachers have to focus on. These other classroom responsibilities relate to behaviour management, duty of care and dealing with students in which confidential information has to be shared.

According to Wenger (1998), CoP practice "is a complex, collectively negotiated response to what participants understand to be their situation" (p. 78). Teachers are trained and experienced in teaching and learning. This is a role with many facets and complexities. However, for a CoP to develop, participants must develop an enterprise that is "communally negotiated" (p. 78). Some aspects of that role in relation to integrating technology can be seen in the interactions between the teachers and the SDLs in the cases studies. Other dimensions of a teacher's role, however, cannot. These seem to be far more intricate and form the barriers that are seen to exist between the teachers and the SDLs.

In the context of this research study and, indeed, when looking at the teachers and students in SDL roles, all teachers commented that these barriers related to trust will always exist. Roger encapsulates the essence of how many of the teachers in this research study seem to feel about their relationships with SDLs: "There are some differences, some conversations I wouldn't have, some stuff I wouldn't do" (Roger, interview, 5 December 2017). Hence, it can be concluded that when teachers and SDLs work together, despite their being conditions from which a CoP can develop, such CoPs are unlikely to develop.

Further application of the CoP lens revealed that trajectories are also relevant when looking at the notion of barriers for SDLs. Wenger (1998) talked about organisational structures that enable newcomers to an organisation to be mentored by old-timers. The newcomers are on trajectories to have more centripetal positions in the CoPs around the practices the organisation is involved in. The old-timers are in positions to assist the newcomers to work towards becoming more established members of their CoPs. However, in this research study, the SDLs were not on trajectories to become teachers. As already discussed, the teachers cited issues with trusting the SDLs, for example, in respect of sharing confidential information and expecting the SDLs to take on other dimensions of a teacher's role, such as behaviour management. The pre-existing roles that teachers and students generally have in schools influence how the teachers and SDLs relate to each other. All these factors contribute to the reason the SDLs remain in peripheral participants in existing teacher

CoPs, except in terms of technology integration.

Hence, what can be seen in this discussion point are circumstances that highlight how the SDLs in this study were in peripheral positions in the PBL teachers' CoPs. Despite the barriers they faced in accessing more centripetal positions in most aspects of teaching practice, the SDLs could still positively influence and share community dimensions of practice with teachers in respect of technology integration. The SDLs positively influenced teacher knowledge and practice from peripheral positions, taking on roles both in preparation for teaching and in classroom situations.

As has already been highlighted, there are barriers erected for SDLs to move beyond the periphery of teacher CoPs, which teachers relate to their inability to fully trust SDLs, given that they are students. The factors that underpin the notion of trust seem to relate to teacher professionalism, to the roles and responsibilities that teachers are expected to have, in other words, a lack of joint enterprise in these key areas of a teacher's roles and responsibilities. It could be that the training of teachers, the qualifications and professional memberships – in other words, the culture and institutions around being a qualified teacher – contribute to difficulties in establishing a joint enterprise with students in SDL roles. However, that would need investigation that goes beyond this research study.

A contrasting and long-term view to address the barriers and the peripheral position of SDLs working with teachers was evidenced in the data. Roger talked about there being a "goal … to move into a position where the SDLs are feeling like the teachers" (Roger, interview, 5 December 2017) , despite later in the same interview explaining elements of his practice he would not share with the SDLs. This hints at possibilities of barriers for the SDLs being removed or at least reduced for more than just technology integration. It could be interpreted as being dependent on time, a long-term goal. It suggests that strategies which look to develop enterprise could be incorporated. However, the comment was not explored further, and thus is also a matter for further research.

What has been reinforced in this discussion is the point made early in Case study 1: CoPs do not form just because people work or learn together (Akinyemi & Rembe, 2017; Brouwer et al., 2012; Patton & Parker, 2017). The formation of CoPs appears to be even more problematic between SDLs and teachers when there are such well-defined pre-existing roles as teachers and students have. In addition, evidence in this discussion point highlights how CoPs "can connect with those, not on a trajectory to become full members…by offering various forms of casual but legitimate access to a practice without subjecting them to the demands of full membership" (Wenger, 1998, p. 117). Relationships clearly developed between the teachers and the SDLs. Both parties appear to participate in a CoP, yet the SDLs remained on the periphery for the most part. Certain aspects of teacher responsibilities in those CoPs, for example, behaviour management of a class, excluded the involvement of the SDLs. They are areas that teachers do not see that they share enterprise with SDLs in, or as suggested in Wenger, there are responsibilities that are part of "the demands" of those CoP members in more centripetal positions.

However, the point of this discussion is not whether a CoP developed or not. A CoP lens has been used as it provides a way to look at social interactions between the teachers and SDLs. It has been established that the SDLs remained on the periphery of any CoPs involving the PBL teachers, except where there were issues related to technology integration. They were in positions that had them influence teachers, but these did not seem to be beyond what the teachers granted them. The periphery can be an area of the CoP where connections are made "with the rest of the world" (Wenger, 1998, p. 117). Wenger talked about how this area can provide experiences to those not on trajectories to full membership and allow outsiders to be engaged in the practices of the community. Such involvement from those typically outside a CoP can provide "opportunities for learning both for outsiders and for communities" (p. 117). These "opportunities" seem to illustrate exactly what was experienced by the teachers working with the SDLs in this research study. Thus, the barriers that teachers put in front of the SDLs in most areas of their teaching practice did not prevent the SDLs influencing

teachers' knowledge and practice in respect of technology. Instead, as Wenger pointed out, peripheries are "a very fertile area for change" (p. 118) which offer great potential to develop the practices of the community. The introduction of the SDLs to teacher CoPs can be a catalyst for advancement of the community's practices and, henceforth, of its members' practice. Wenger talked about there being layers of membership going from centripetal to peripheral. He explained that having these layers "affords multiple and diverse opportunities for learning" (p. 118). This affirms the idea that the SDLs in this research study were in a position on the periphery to influence the learning of the community and its members. As to whether that actually then led to the SDLs influencing the knowledge and practice of teachers is explored in further discussion points.

This discussion point has highlighted that the SDLs worked on the periphery of teacher CoPs in this research study. In the next discussion point, SDLs in brokering roles will be a major part of the discussion. This will focus on how they function in peripheral positions, the role of boundaries and, ultimately, how the concept of boundaries as described in Wenger can be challenged.

9.2. SDLs as brokers and CoP boundaries that shift under specific conditions

This section continues with the theme that the SDLs worked on the periphery of the CoPs involving teachers. This section discusses those peripheral positions as brokering roles. In brokering roles, the SDLs were able to influence the practice of the teachers they worked with. However, their degree of influence was constrained by the boundaries that were maintained by the teachers, which ultimately ensured that the SDLs remained at the periphery of teacher practice for the most part. From there, the discussion will centre on how, in certain situations, given specific conditions, these boundaries shifted. This provides a unique perspective on how boundaries can be in place or shift conditionally.

This research study involved a number of SDLs working with PBL teaching teams. It was

organised so that numerous SDLs could assist teachers in their classrooms, and particular SDLs were involved in the software training and pedagogical discussion sessions. In other words, on several occasions, some SDLs worked with a few different teachers and shared practices from one PBL teaching team CoP to another. This positioned the SDLs in brokering roles where they were able to "introduce elements of one practice to another" (Wenger, 1998, p. 105). Through these brokering roles, the SDLs influenced the practice of all teachers in the case studies. This was seen when they provided in-class assistance to the teachers. Paul from Case study 1 as well as both Marg and Faith from Case study 2 adopted different roles in their PBL classrooms when the SDLs assisted, focusing more on behaviour management of the students. Roger from Case study 1, Tom and Emma from Case study 3 changed their approach to integrating technology when they had the SDLs provide in-class assistance. Even where there was no in-class assistance provided, through advice given by the SDLs and questions answered in the pedagogical session, the SDLs' influence on practice could be seen in Finn's case study.

However, if we consider the concept of practice viewed through a CoP lens, it is "a source of coherence of a community" (Wenger, 1998, p. 49). Thus, it can be broken down into mutual engagement, joint enterprise and shared repertoire. The way that the SDLs operated in brokering roles varied between the teachers they worked with, although their approaches seemed to develop from foundations of being mutually engaged, working towards an enterprise of teaching technology to PBL students. At times, they seemed to provide in-class assistance such as demonstrating how to use the software, advising on how best to approach certain designs online and assisting students struggling to develop skills with the technology, based on what they considered to be the best approach. However, at other times, the SDLs were given direct instructions by the teacher.

Both Roger and Tom gave the SDLs quite specific instructions as to what they were expected to do, how they were expected to participate and, essentially, what their roles were. This is not an attempt to suggest that the SDLs were non-contributors to discussions in these

matters in the pedagogical session, or, as in the example of Tom, just prior to providing in-class assistance. Their engagement and a focus on the enterprise can be seen in observations and comments made across the case studies. Both Roger and Tom talked about how the SDLs made suggestions and offered opinions from their experiences gathered through their brokering roles moving between the PBL teaching teams and through preparations in becoming SDLs. As well as highlighting the contributions the SDLs can make to influencing teachers' practice when they are prepared for such roles and given the opportunity to work with different teachers, this shows the contributions that SDLs can make, their repertoire, in offering insight when they have, themselves, taught students how to use technology.

According to Wenger (1998), effective brokers "stay at the boundaries of many practices rather than move to the core of any one practice" (p. 109). In this study, the SDLs operated between the teaching teams and influenced teachers' practice in respect of technology integration. However, as discussed in Section 9.1, they faced barriers to moving beyond peripheral positions in teacher CoPs and instead stayed "at the boundaries" of much of the practice of a CoP involving PBL teachers. This practice involved, for example, behaviour management and duty of care over the students.

According to Wenger (1998), boundaries "refer to discontinuities, to lines of distinction between inside and outside, membership and nonmembership, inclusion and exclusion" (p. 120). A. Cox (2005) highlighted that it is often difficult to identify boundaries, saying that they "can be vague" and formed around "ambiguous symbols" (p. 12). Wenger described boundaries as different to peripheries, which offer "possibilities for participation" (p. 120), but the two "are woven together" (p. 120). He then went on to talk about his own experiences working with claims processors, describing how this "sometimes felt like full participation, but every so often elements of boundary would creep in to remind me that I was an outsider" (p. 120). Hence, it can be seen that peripherality has its own ambiguities as CoPs can provide participants with the feeling that they are being allowed to participate fully, only for the boundaries preventing this to return. Thus, to summarise all of this, when looking at

boundaries and peripheries in CoPs, their existence is often understood clearly by participants in centripetal positions, but they tend to shift and can be difficult to identify, particularly for those on the periphery or outside of CoPs.

What is clear in this research study is that systematic boundaries related to the teaching profession and teachers' legal responsibility to provide a duty of care prevented the SDLs from having more centripetal positions, for the most part, when working with the teachers. The SDLs remained largely on the periphery of CoPs, operating beyond the boundaries related to the professionalism and accountability of teachers for their students. Although teachers in this research study referred to these boundaries as the inability to fully trust the SDLs, trust was not mentioned in Wenger (1998). Similarly, lack of trust was not featured in Wenger's work with regard to boundaries of CoPs. On closer examination using a CoP lens, what is more applicable here is the issue of joint enterprise. The teachers said that they felt there would always be some limits to the joint enterprise they could have with the SDLs and, as already discussed, the SDLs were given legitimacy only as brokers, largely on the periphery of teacher CoPs, participating beyond a certain point only under certain circumstances.

Given the boundaries related to duty of care and professionalism of the teachers involved in the research study, it seems surprising that, in three out of the four case studies featured, the SDLs were seen to make their own decisions when working with the students in the class. Where the teachers commented on these instances of the SDLs' independent decision-making, they revealed mutuality and a shared approach to technology integration. This can be seen when Tom talked about how the SDLs "came up to him afterwards and they had tried something and it didn't work so they used their initiative and it was fine" (Tom, interview, 29 November 2017). Roger talked about how he utilised "the students more as facilitators rather than instruction givers which works better for him" (Roger, interview, 5 December 2017).

In Marg and Faith's case, the SDLs worked largely independently of the teachers, and

Marg recalled that she "spoke to one of the SDLs about the student's progress … about what they were doing, how things were going and how the SDLs were actually helping people so I could maybe do something in the future" (Marg, interview, 5 December 2017). This again highlights that, even without actual sharing the teaching of PBL students about technology, there was an understood, mutual goal regarding the students' progress. It could even be said that Marg was imagining the role that she would be playing after the SDLs ceased their involvement. In Case study 4, featuring Finn, there was no in-class assistance. but even in that case, the teacher described how he benefitted from working with the SDLs: "The SDLs were able to skill us teachers up meant that we then had the skills to help the students" (Finn, interview, 8 December 2017). His comments give a sense of a joint enterprise, being mutually engaged in acquiring skills and knowledge to approach technology integration in the PBL classes.

Hence, there seems to be a situation arising out of this research study where the boundaries set by the teachers preventing the SDLs moving beyond the peripheries of teacher CoPs seem to shift, given certain circumstances. The teachers were happy to have the SDLs take on more responsibility in their classrooms and work more autonomously when the teacher is focused on other areas of classroom practice, such as behaviour management. This temporarily put the SDLs in positions where they shared more practices and accountability with the teachers. They also showed "a negotiated response to their situation" (Wenger, 1998, p. 77), exhibiting joint enterprise characteristics with the PBL teachers. This is despite the consensus of opinion of the teachers involved that trust issues prevented them from forming CoPs with the SDLs.

In Wenger (1998), boundaries are referred to as being flexible. Roberts (2006) extended this idea of flexible boundaries, stating they are "continuously shifting" (p. 4). The difference in this research study is in terms of the specificity of the conditions for shifting the boundaries. These specific conditions centre on the SDLs being involved in classrooms with the teachers. In these conditions, the SDLs were permitted to operate independently of teacher direction, crossing boundaries related to the teacher's duty of care and their management of

the class. This is far more specific than the description of "opening and closing, limits and latitude" (Wenger, 1998, p. 121) for how boundaries and peripheries typically operate. It also shows the boundaries to be dependent on particular circumstances.

The circumstances around the shifting of boundaries seem to be related to situations where the teachers can give up certain elements of control while remaining in charge of the whole class. In other words, the SDLs were given constrained legitimacy of practice. With reference to the characteristics of dimensions of practice provided in Table 2, the SDLs were able to engage in mutuality, have recognition of joint enterprise and have a shared repertoire that is accepted. However, this was permitted to occur only when the teacher retained their status and had overall duty of care for the class. In the case studies where the SDLs provided in-class assistance, they largely worked with small groups of students. This is when the SDLs were given autonomy to make their own decisions and were seen to work independently of the teacher, and the teachers commented positively on their doing so.

This idea of the teachers retaining their status and that their status is a factor in their being in control of a class also brings in the concept of identity. From the comments of two of the teachers in the research, it could be argued that a shift in CoP boundaries seems to occur only when teachers' identities are not affected. Roger described that he "didn't see the SDLs as in charge and they didn't see themselves as in charge. We had had the discussions and stuff but, erm, they didn't see themselves as the people in charge of the situation" (Roger, interview, 5 December 2017). He remained the teacher of the class and retained his identity as the professional with the overall responsibility for the class and the students being taught.

Faith seemed to recognise the need to involve herself in the integration of technology even when the SDLs provided assistance in class:

> [I don't] want to be pushed out. I don't want my kids looking at me like, 'you don't know what you're doing'. Cos it's not realistic that SDLs are going to be in every lesson. Erm, I think a team approach is what's gonna work best. (Faith, interview, 5 December 2017)

She recognised a need to be seen as someone the students can learn from, who can assist them and teach them, highlighting her desire to retain those aspects of a teacher's identity in the eyes of her students. This could be interpreted as Faith's willingness to involve the SDLs but only when it does not affect her standing in the classroom, her identity as a classroom practitioner. It must be noted, however, that only these two teachers made comments with reference to this point, and as such, the matter remains somewhat unclear. A larger discussion on the various aspects of identity is required. Hence, it is a discussion point in itself and is covered in greater detail in Section 9.5.

In summary, the SDLs working on the periphery of the PBL teachers' CoPs have influenced the practice through brokering roles. The barriers of trust that have been described by teachers can be interpreted as CoP boundary conditions, as outlined in Wenger (1998). Understanding the boundaries and peripheries of CoPs can be fraught with difficulties, according to Wenger. Boundaries are flexible and coalesce with peripheries. People can seem as if they are part of communities, participating with its members, only to find that boundaries are still in place at certain stages, meaning they remain on the peripheries. However, evidence from the case studies shows that the SDLs still influenced teachers' practice in respect of integrating technology from peripheral positions in the teachers' CoPs. This is despite the amorphous nature of peripheries and boundaries. When working with the teachers during in-class assistance, the SDLs found barriers of trust that created boundaries to CoPs shift temporarily. These shifts were not that far removed from the flexile nature they are said to have by Wenger and by other researchers looking at this area. What this discussion adds is a description of specific conditions when the shifts occur, and that specificity extends the research in this field.

This section has provided a discussion on the SDLs operating in brokering roles for the teachers' CoPs around the teaching of PBL. It has offered an extension to existing research in terms of the specific conditions that can lead to the shifting of CoP boundaries rather than the more ambiguous description of their flexibility typically found in CoP research. In respect of

the research question, this section has provided evidence of how teachers' practice can be influenced by having the SDLs provide in-class assistance, and, in Tom's case, his practice was also influenced through the pedagogical discussion session. These teachers operated differently in the classroom as a result of the involvement of the SDLs or, for Tom, as a result of their advice. The focus has been on practice for this discussion point. In the next section, teachers' knowledge will be the focus.

9.3. SDLs' influence on teachers' TPK, subsequent changes in practice and distributed TPACK

This section primarily uses a TPACK lens although there is also continued use of a CoP lens as in previous discussion points. It looks at the degree to which the SDLs influenced the teachers' knowledge when integrating technology. The discussion commences with a look at TK but quickly moves on to TPK. It shows that working with the SDLs can lead to advancement in teachers' TPK when trying to integrate technology and discusses how that happens. However, the cases studies also reveal that increases in teachers' TPK does not necessarily lead to subsequent changes in practice and that this is at the discretion of the teacher. The reasons this occurs for some teachers and not for others highlight the significance of the degree to which teachers involve themselves in classroom technology integration; in other words, how they mutually engage with the SDLs in the classroom. The concept of distributed TPACK features heavily in this section, with evidence presented on how TK is shared between the SDLs and the teachers. However, I also show how the case studies reveal challenges to existing research on distributed TPACK with TPK also being shared.

TPACK was defined in Section 2.1. (The TPACK framework). The forms of knowledge and the intersection between these which make up the framework shown in Figure 1 were explained in the subsections of that chapter. The framework has often been used to "measure teachers' knowledge and to explain teachers' use and non-use of digital technologies" (M. D.

Phillips, 2014, p. 558). As this section focuses on the degree to which teachers' knowledge is influenced by the SDLs when integrating technology, the framework from Figure 1 plays a central role. Although not attempting to empirically measure teachers' TPACK, the first source of evidence to be analysed in this section is data recorded from the interview responses.

Data from Table 5 clearly indicates that working with the SDLs positively influenced all teachers' TK. Their responses to the question "Do you think your knowledge & practice have advanced in respect of this particular software as a result of being trained by the SDLs?" were positive for every teacher. Responses from all teachers in the reflective interviews support this claim. They can be seen throughout the case studies. However, in many ways, advancement in TK is generally an expected outcome from software training. Therefore, arguably, the SDLs' influence on the teachers could easily have been foreseen in this regard. What is worth noting, though, are the teachers' comments around how the SDLs worked with them during the software training session, which provide a relatively in-depth appraisal of the SDLs' influence. Examples of these are provided in the next paragraph.

Marg saw benefits from gaining TK from the SDLs related to the SDLs being of a similar age to the PBL students in her class: "How they operate the software and the value to the SDLs helps me with understanding the value to my students as well, considering they are a similar age" (Marg, interview, 5 December 2017); Faith commented that she valued the SDLs' training and teaching techniques in the software training session, recognising the support it provided her: "The SDLs were more, 'have you tried this? Have tried this?' They were really good at pointing that out and going through that with me" (Faith, interview, 5 December 2017); Paul recognised that the SDLs provided opportunities for learning that were accessible to the teachers in the session: "SDLs kept it at an understandable level" (Paul, interview, 6 December 2017); Finn valued that the SDLs shared knowledge and experience from their own learning and teaching using the technology: "SDLs had awareness of the issues that might arise" (Finn, interview, 8 December 2017).

The comments in the previous paragraph seem to have a common theme running through them. In the eyes of the teachers, the SDLs offered a unique perspective on the software. The teachers considered the angle and viewpoint of the SDLs be those of a learner, akin to the PBL students the teachers were planning to teach. Their comments suggest that from a learner's perspective software training enabled them to easily access the knowledge the SDLs were trying to impart. It also suggests that the SDLs' approach to the training provided knowledge and confidence that teachers in the process of planning for upcoming PBL classes valued.

Focusing with more depth on the type of knowledge the SDLs seemed to provide for the teachers in the software training session suggests influence beyond TK and more towards TPK. Marg referenced the SDLs being of a "similar age" to her PBL students. Finn recognised that the SDLs had learner perspectives in respect of understanding what problems might be faced when learning how to use the software. These seem to refer to how the SDLs' approach, the information they provided in respect of using the technology, led the teachers to consider how their PBL students would respond to having to learn these same skills. This indicates that these teachers were imagining the classroom practice they would be involved in and the responses of their students to the intricacies and nuances of the software the teachers would introduce to them. However, it is from the pedagogical discussion session that the SDLs' influence on TPK can really be seen. This is the theme of the next few paragraphs.

Roger, Tom and Finn all engaged in the pedagogical discussion session and were observed conversing with the SDLs on approaches to teaching 3D design. They questioned the SDLs, sought their advice and opinions and seemed to value their expertise in being able to teach students how to use the technology. An example of this can be seen in this question put to the SDLs by Roger at the opening of the pedagogical discussion session: "Would it work well if, because we will have students with different needs … to group students not necessarily on skills and experience, but on what they intend to get out of using the software?" (Researcher observations, 1 November 2017). Much of the pedagogical discussion continued to explore

ideas around grouping of students in the learning of the software, how best to coordinate activities around technology integration with factors such as differentiation to address. Comments by all of these teachers reflect how much they valued the contributions the SDLs made to their TPK during these sessions. The teachers and the SDLs exhibited examples of dimensions of practice, as described in Table 2. They had mutuality, were negotiating their enterprise and developing a shared repertoire around the teaching of technology.

Emma had a separate one-on-one pedagogical discussion session with a SDL as she could not attend the arranged session. The conversation between the SDL and the teacher, in this session, focused largely on how best to teach students the technology. The discussion paralleled much of the themes in the larger session discussed earlier, where the SDLs provided information and advice that led teachers to consider how their PBL students would respond to having to learn these same skills. Emma said afterwards, in the reflective interviews, that working with a SDL and gaining this insight "was really handy cos it made planning to teach it really easy" (Emma, interview, 6 December 2017). Hence, again, a teacher's positive views on this involvement with the SDLs can be seen as a specific part that the SDLs played in influencing the teachers' intended approaches to classroom practice. This supports earlier points made on how the SDLs influenced teachers' TPK and fuelled their imagination, as defined in Section 2.3. (Participation and non-participation).

Thus, it seems worthwhile at this juncture to summarise what has been said in this discussion point, namely how teachers seemed to view the benefits of discussions on pedagogy between themselves and the SDLs. They seemed to value the SDLs' contributions to ideas and planning on how to integrate technology and approaches to use with students in classrooms. As to whether a pedagogical discussion session is the best approach is a matter for further research. It was the method used in this research study, and there is no other approach for comparison. From observations of the software training session and comments made by the teachers in the reflective interviews, instances of teachers' TPK being influenced can be seen. However, the research question concerned how the SDLs influence not just

knowledge but also practice. Given this, attention now turns to whether influences on knowledge led to changes in practice.

As already discussed in Section 9.2, a number of teachers talked about having their classroom practice influenced by the SDLs during in-class assistance. It was shown that the involvement of SDLs in classrooms affected teachers' practice, their approaches to integrating technology. However, even when there was no in-class assistance provided, as in the case of Finn, TPK gained from the SDLs influenced how he taught students the use of the software. However, in the reflective interviews, two teachers talked about the SDLs' influence on their practice in different, quite negative, ways. Tom talked about how the SDLs were not provided with "a situation where they could give ideas that could be applicable" (Tom, interview, 29 November 2017). He suggested that although their ideas on pedagogical approaches to teaching 3D design gave valuable insight, the way his class was organised and the events that happened on the day meant their ideas could not be applied. In other words, the knowledge they provided, although valuable, did not manifest into practice. Similarly, Roger said, the SDLs had not influenced him "in the way I would run things" (Roger, interview, 5 December 2017). This suggests the TPK that the SDLs provided did not influence subsequent classroom practice. However, with both Tom and Roger, observations of in-class assistance seem to contradict with their views. What I saw in the classroom highlights that their practice was actually influenced by the SDLs, despite their claims that it was not. Both of them had the SDLs working with groups of students. In Roger's case, the SDLs introduced the software to the whole class. Without the SDLs in this role, he or Paul would have had to take on that responsibility. This would have likely meant different classroom practice during this time; a similar comment can be made for Tom if the SDLs had not provided in-class assistance with groups of PBL students in his and Emma's class.

To attempt to summarise the perspectives of Roger and Tom and how these relate to TPK and influences on teacher practice, it is clear that there are instances of SDLs influencing both teachers' knowledge and practice. However, it may not always be the case that influences on

knowledge manifest into subsequent practice. In other words, TPK such as how best to organise groupings of students to teach them aspects of technology may be good ideas, valuable knowledge that is provided for a teacher. However, a situation can be easily foreseen where, in the throes of a lesson, such knowledge may not become practice due to a teacher's decision to not take on the advice and act on the knowledge gained from the SDLs. Again, this relates to the idea that the teacher remains in control of the class and the events in that class. As discussed in Sections 9.1 and 9.2, the teacher shifts the CoP boundaries, to allow the influence to occur but, ultimately, they remain as the person who decides the degree of influence that the SDLs have on classroom practice.

Thus, to relate this back to research in this area, what has been seen here provides additional contributions. Teachers in CoPs can be influenced by those on the periphery or in brokering roles, but changing practice requires a shift in boundaries to facilitate any changes stemming from the influence on knowledge. As already discussed, when teachers work with the SDLs, , there are issues of trust with an underlying lack of joint enterprise. These create barriers for the SDLs to move beyond peripheral positions in any areas, except the integration of technology. This means that when SDLs influence from this CoP peripheral position, any decisions as regards when and where knowledge acquired from the SDLs leads to changes in practice occur at the discretion of the teachers. In other words, when increases in TPACK lead to subsequent changes in practice, is also at the discretion of the teacher. However, there is also another aspect of this discussion point that seems to add to research in respect of distributed TPACK, and that follows in the paragraphs below.

Distributed TPACK stemmed from the notion that knowledge is not necessarily held by an individual nor does it have to be when teachers integrate technology. Described at length in Section 2.1. (Knowledge development in TPACK), distributed TPACK was first suggested by Nore et al. (2010), furthered by Di Blas, Fiore, et al. (2014), Di Blas, Paolini, et al. (2014) and Di Blas (2016a, 2016b). However, as highlighted in that same section, their work and all subsequent research that was found from searches of academic libraries did not focus on

TPK. Indeed, according to Di Blas and Paolini (2017), distributed knowledge appears not to include pedagogy. Teachers are expected to have this type of knowledge. However, in Case study 4, the focus was largely on how the SDLs shared knowledge with Finn on the best approaches to teaching technology in his PBL class. In other words, the SDLs provided TPK in the pedagogical discussion session, not just TK in the software training session. Similarly, the discussions earlier in this section highlighted the SDLs' sharing of TPK with all the teachers who attended the pedagogical discussion sessions.

Marg's comments on the software training session also suggest that the knowledge shared by the SDLs at this stage was pedagogical as well as technical. She was asked in the reflective interviews whether she thought the SDLs talked more about learning in the software training session than a teacher providing the same training would. She said that they did, adding that it was "from a student perspective. Exactly how they would use it in their learning and how it would benefit them in their learning" (Marg, interview, 5 December 2017). This suggests that Marg was thinking about the way the SDLs interacted with the software, how they learned to use it and, possibly, imagining how she could approach teaching her own class or, at least, how the PBL students in her class would learn to use the software.

Faith recalled events in the software training session that relate similarly to the SDLs sharing TPK with her: "I remember saying to a few of them, 'I don't think my class'll understand that. I can't understand this. How do I get my class to understand this?'" (Faith, interview, 5 December 2017). Again, there is a suggestion here that the teacher was thinking ahead as to how the PBL students would react to the technology they would be introduced to and how would affect her teaching practice. She was imagining how the struggles she was having in understanding how to use the software would manifest when she tried to teach the PBL students the same technology.

Thus, there is substantial evidence across the case studies that teachers provided with opportunities to discuss pedagogical approaches to technology integration into their

classrooms can have their TPK as well as their TK influenced by the SDLs. This type of pedagogical knowledge can be shared with the teachers, it need not be held by the teachers, but can be distributed knowledge. However, there are other factors that determine how the SDLs can influence teachers' practice; one that seems to appear in much of the data collected relates to teachers' identities, which has already been touched upon in this and other discussion points briefly. This will be the focus of the next section.

9.4. The significance of teachers' identities on SDLs' effectiveness

In this discussion point, the concept of identity is the main focus. Using a CoP lens, data on teachers' identities in the case studies is synthesised. This involves looking specifically at the role that teachers' trajectories and alignment played in how the teachers worked with the SDLs during this research. The significance of what was seen can then be related to the research question and aspects of teachers' knowledge and practice. Given the significance of identity, trajectories and alignment in this section, reminders of what these are in CoP terms are provided at the outset.

Identity, in the context of a CoP as defined in Wenger (1998), was described in Section 2.3. (Understanding the concept of identity). This gave a sense of how the concept cannot be simplified and understood from just an individual's perspective nor can it be seen as being "abstractly collective" (p. 146). Identity is the reification of the individual and their position in the community. In this sense, it is "shaped by belonging to a community but with a unique identity" (p. 146). Figure 3 highlighted how entwined identity and practice are in CoPs. The formation of identity is a product of participation in CoPs, which provides ways for individuals to understand and shape their roles and perspectives (Wenger, 1998).

Trajectories can be explained as the concept of identities continually developing, shaped by CoP participation. As shown in Section 2.3. (Trajectories), the role of trajectories is that they "connect the past, the present and the future" of an individual (Wenger, 1998, p. 154). This describes how past events in people's lives, current events, roles and positions in CoPs

as well as where people see themselves in the future all contribute to an individual's identity.

Alignment was described in Section 2.3. (Participation and non-partipation). This is the concept of members having practices that demonstrate their willingness to be part of a "broader social system" (Wenger, 1998, p. 179) and align with "expectations of employers" (p. 179). It is an aspect of identity that is not dependent on other aspects of identity, according to Wenger (1998). For example, mutual engagement can occur with or without aligning practice to the overall enterprise of an organisation.

Table 4 provided an overview of some aspects of teachers' identities at the outset of this study. It gave a brief insight into their views, experience, perceived skills and confidence in the use of technology in their practice. It also provided information on previous experience and the teachers' level of optimism towards working with the SDLs. The table shows that there were three teachers, Emma, Marg and Faith, who provided very similar self-reported views. They scored themselves low in terms of both confidence and skills in using digital technology as part of their teaching practice. Also, none of them had previously been trained by students in the use of digital technology or had in-class assistance from the SDLs prior to this study. Given that these three teachers seem to have very similar traits at the outset of this research, the next two sections focus on how they worked with the SDLs.

Emma quickly built relationships with one SDL in particular, after requesting an opportunity to discuss pedagogical approaches to teaching with the technology, as she had missed the planned session. In this session, there was "an open atmosphere of sharing between teacher and [SDL name]" (Researcher observations, 25 September 2017). Emma clearly saw the value in discussing how to approach the integration of technology into her PBL class in the fact that she asked for the session but also in her approach to the session. There was mutual engagement, joint enterprise and shared repertoire between her and the SDL, which was described in Section 7.1. (Developing CoP dimensions with the SDLs). Emma seemed focused on having the SDL assist her in advancing her TPK.

As shown in Table 3, Marg and Faith were very much newcomers to CoPs around the teaching of PBL at the school. Neither teacher had taught PBL previously, Faith joined the school at the start of the year, and Marg joined mid-year. They were also inexperienced in the teaching profession. Figure 7 highlights that they did not attend the pedagogical discussion session. Observations and their responses to interview questions reveal that Marg and Faith's PBL class were introduced to the technology by Paul, Roger and the SDLs without their being present. Follow-up sessions in Marg and Faith's class saw the SDLs providing in-class assistance. However, Marg and Faith's involvement in this process was minimal.

Thus, in summary, Emma had both software training and dedicated time with a SDL to advance her knowledge in how to approach teaching with the technology. She positioned herself with the SDLs so as to have them influence her knowledge and possibly her practice. Marg and Faith were not greatly involved in the integration of technology in their classroom practice. Likewise, they did not appear to have positioned themselves with the SDLs or with their own PBL students to advance their knowledge and practice in respect of teaching with the technology. However, so far, the emphasis has been on what actually happened to Emma, Marg and Faith. There has been no consideration as to how this happened and how that relates to the events described. This is where identity, in particular the sub-categories of alignment and trajectories, are worth examining.

On more than one occasion in the interviews, Emma talked about how she felt "comfortable" with the SDLs in admitting that she "really didn't know what she was doing" (Emma, interview, 6 December 2017). She also highlighted that "seeing the SDLs' confidence with the software, gave me confidence," (Emma, interview, 6 December 2017). This demonstrates her willingness to mutually engage with the SDLs, share a joint enterprise, despite admitting a lack of confidence. Emma showed that she was aligned to both the school's drive for more student voice and student action as well as the underlying skills the PBL students needed for the project, namely prototyping. She stated, "It's important for us to hear their voice" (Emma, interview, 6 December 2017) with "their" being the SDLs and "us"

being the teachers. Such a view on how she sees not only her own response but also that of her fellow teachers in many ways reinforces the sense of her alignment to the active involvement of the SDLs. In addition, Emma directly linked the need to integrate technology with giving the PBL students the opportunity to prototype using 3D design during their project development. She recognised the value in the PBL students developing skills with the technology and thus aligned herself to the school's drive to promote agency in students, committing to developing her own knowledge and skills in the area.

Further comments about past experiences reveal aspects of Emma's identity and how her approach detailed above seemed to be based on past experiences and trajectory influences. She described one such experience in detail:

> I once had a Year 8 class and they did procedure and they taught me how to kick a football beautifully. Cos they knew how to hold a ball, how to do it. They were so good at explaining every single step, how many steps to take, which leg I started on. (Emma, interview, 6 December 2017)

Emma clearly aligned herself to the benefits of student voice. She highlighted not only what the students did and why they did it but also the effect it had on her. Therefore, this reflection indicates the influence of a past event on her desire to advocate for student voice and agency in her practice.

Marg and Faith's responses, in many ways, contrast with Emma's. They did not provide any strong evidence of alignment in the same way Emma did; that is not to say they criticised the involvement of the SDLs in the project. They offered many positive comments on the SDLs' contributions and invited them to provide in-class assistance. Likewise, Marg and Faith's actions in ensuring their PBL students were introduced to the technology by Paul, Roger and the SDLs "because they have more skills and knowledge basically" signify alignment to ensuring their students were equipped to use the software (Marg, interview, 5 December 2017). However, in respect of trajectories, Marg, and particularly Faith, differ greatly from Emma, not just in terms of past trajectories but also current and, possibly, future

trajectories as well.

Marg and Faith's case study shows that they struggled with understanding the fundamentals of the software they were being trained on. Marg talked about having her "own barriers in terms of being able to work with the programs" (Marg, interview, 5 December 2017). Faith said she felt "really uncomfortable" during the software training session and she struggled greatly using the software without the SDLs' assistance after that event (Faith, interview, 5 December 2017). She then offered far greater insight, talking about past issues with learning how to use technology. She offered comments such as "It's just a part of my brain that I can't. I don't know what it is"; "it wasn't until about halfway through the session that I hit a wall and I was just like, 'it's all happening again'" (Faith, interview, 5 December 2017). These describe not only how Faith felt in the training session but also how it reignited feelings she had previously encountered.

Both Marg and Faith's comments relate to trajectories. For Marg, it is not clear whether her issues with the technology were based on something in the past or something more current, whereas Faith's issues were clearly related to past trajectories in trying to work with technology. However, there are also future trajectories, unrelated to technology, which are contributing factors for both these teachers. Unlike Emma, Marg and Faith were relatively new to the profession, they were new to the school and to PBL. It is understandable to assume that their foci were on future trajectories to establishing themselves in the school, to moving from peripheral to more centripetal CoP positions. Support for this claim can be seen in Section 6.2. This featured Faith's comments on having her own "complex" due to missing much of the preparatory work leading up to the launch of PBL. She described this as putting her "on the back foot" going into this unit, where she knew she may have issues with grasping the fundamentals of the technology (Faith, interview, 5 December 2017). As already discussed, Marg and Faith had Paul, Roger and the SDLs introduce the technology to their students, then the SDLs provided the bulk of the assistance in the class. This seems to reflect Marg and Faith's reactions to their struggles with technology as well as their own desire to

focus on aspects of their trajectories which would benefit them the most. In observations, those aspects seem to relate to class and behaviour management.

Thus, to summarise what can be seen up to this point in the discussion, despite the similarities of Emma to Marg and Faith in respect of self-reported views on low confidence and skills in using digital technology as part of their teaching practice, Emma's response was entirely different. She sought out the pedagogical influence of the SDLs and positioned herself to advance her knowledge. Marg and Faith did not. They, also, in many ways distanced themselves from involvement with integrating the technology in their practice, by having Paul, Roger and the SDLs heavily supplement their roles in this regard. The underlying reasons seem to relate to their alignment and trajectories. These elements of identity influenced their decisions, focus areas for the advancement of their practice and, ultimately, their actions. This saw them in contrasting positions in terms of the capacity to have their knowledge and practice influenced by the SDLs.

Further support for the claim that alignment and trajectories play a role in the degree of influence the SDLs can have on teachers' knowledge and practice can also be seen with the other teachers. In Section 5.1. (The ways in which a teacher's identity and participation are linked to the influence of SDLs on their knowledge and proactice)1, commenting on researcher observations, Paul admitted that he and Roger had discussed the roles that each of them would take in the teaching team for this project. He decided on a behaviour management role, while Roger took on the role of trying to integrate technology into the classroom. In providing the reasoning behind these decisions, Paul revealed how they related to his inbound trajectory in the school. He said that he knew he was "gonna have the PBL students later on" and how the behaviour management role enabled him to get "some sort of rapport" with the students (Paul, interview, 6 December 2017). However, through the discussions and agreements that he made with Roger, Paul also showed a degree of alignment to making the project work and to ensuring the students developed the skills required for the project. This relates to alignment in the sense of how Wenger (1998) described it as "we do what it takes to

play our part" (p. 179), which in this context is contributing to the teaching of PBL to the students.

In the same case study, Roger expressed views on the differing alignments the PBL teachers have, despite working on the same projects and working together in the PBL groups and in PBL teams. His views that the teachers were "not all working to the same goals" (Roger, interview, 5 December 2017) highlight that he recognises that there were teachers on different trajectories with different priorities. With such variations between the teachers, it is easy to see how these differing trajectories affected their involvement, interactions and relationships with the SDLs.

All in all, there has been a substantial amount of evidence provided in this section to highlight the role that identity in the form of alignment and trajectories has played on the way the teachers positioned themselves to work with the SDLs. Teachers with very similar confidence, skill levels and experience with technology can be influenced by the SDLs at different levels. The underlying causes of the different levels of influence are directly related to aspects of the teachers' identities. Roger's comments on the differing alignments of the teachers involved offer perceptive insight into how teachers have their own trajectories, which determine what is important to them. These then, in many ways, determine how they react to the SDLs and to the integration of technology that the SDLs are attempting to influence. The cumulative effect is on the degree of influence the SDLs can have on particular teachers.

In this section and in other discussion points, there have been several mentions of the roles that teachers decided to take in working with SDLs, particularly during in-class assistance. However, there has been no discussion on the significance of team teaching and what part this played in how the SDLs could influence teachers' knowledge and practice during this time. The way that teachers positioned themselves, took on specific roles and participated in planning and designing the lessons involving technology is also an area that needs further

discussion. Both of these are the foci of the next section.

9.5. The significance of team teaching on how SDLs influence teachers

According to Murray (2013), designing professional learning for teachers is a challenging endeavour. Koehler et al. (2004), Koehler et al. (2007) and Voogt et al. (2015) all highlighted the benefits of teams collaborating in designing teaching and learning with technology. Being part of a team-teaching approach empowers teachers to take risks in their practice that they would not take if they were working independently (Evans, 2002). This research study focused on teachers set up in PBL teaching teams and also in PBL groups, where teams could support each other. These teams worked together to design their PBL lessons and taught in teams. The SDLs assisted in both the design phase (providing software training and pedagogical advice) and when ideas were put into practice (providing in-class assistance). This section discusses the impact of team teaching on how SDLs influenced teachers both in preparing to teach PBL classes and when actually teaching. It describes how some teachers were involved in the integration of technology while others were not, and the links to how the existence of teaching teams and groups enabled that.

Section 9.3 discussed how SDLs were shown to influence teachers' knowledge in the software training and pedagogical discussions sessions. It examined evidence of where TK knowledge had been influenced but also where SDLs had provided TPK to teachers, which they could then use in their classroom practice. Focusing firstly on the software training session, having the teachers in teams could be seen to play a part in how the teachers supported each other. Some teachers shared challenges in learning how to use the technology with their peers. Faith described how she shared her and Marg's feelings with her PBL teaching group: "I even said to Roger and Paul, 'you guys seem to have got it really good. Me and Marg are not feeling comfortable'" (Faith, interview, 5 December 2017). Finn recalled events from the software training session, saying, "There were some people who needed a lot

more support and didn't get support. Marg was one of those and I was supporting her" (Finn, interview, 8 December 2017). Finn's actions could be said to have supplemented the work of the SDLs, by assisting teachers in acquiring TK.

Marg and Faith were the only teachers describing the use of their peers for support during the software training session, but that seems to be because they are the only teachers featured in this study who struggled in developing the skills to use the software. None of the other teachers expressed similar difficulties. It could also be argued that support similar to that provided by Finn, Roger and Paul would have occurred even if the teachers were not working in teams. However, when attention is turned to involvement in the pedagogical discussion session and the impact that had on practice, there seems to be a more defined link to the influence that a team-teaching approach had on events. In order to discuss this properly, though, there needs to be a reminder of what occurred in respect of teachers; involvement and lack of involvement during the pedagogical discussion session and when students were being taught with technology in the classroom.

Some teachers chose not to participate in the pedagogical discussion session, while others were actively involved. Figure 7 provides details on which teachers were involved in each session. The pedagogical discussion session was attended by Emma, Roger, Tom and Finn. This meant that the remaining teachers who were part of this study – Marg, Faith and Paul – chose not to participate. When asked about this in the reflective interviews, Paul explained his absence from the session as due to his chosen role in the teaching team and his focus on wanting to "build relationships with the students" (Paul, interview, 6 December 2017). This was highlighted in Case study 1 and discussed in Section 9.4 in relation to his future trajectory.

Marg and Faith chose to largely concentrate on areas of their PBL teaching other than the integration of technology, but this was due to their struggles in developing skills and confidence. In Case study 2, at various points, it was shown how Marg and Faith recognised

that they were finding it hard to grasp the fundamentals of the technology. This then led to an agreement in their PBL teaching group, for students from their class to have "an introduction with Paul and Roger because they have more skills and knowledge than us" (Marg, interview, 5 December 2017). Hence, Paul, Faith and Marg seemed to have decided to participate in the pedagogical discussion session as they were not intending to try to teach the PBL classes with the technology. That role was going to be largely the responsibility of others.

Having established who was and who was not involved in the pedagogical discussion sessions and some of the reasoning for not participating, attention can be shifted to the actual lessons for these teachers; firstly, where PBL students were introduced to the software being used, and secondly, when SDLs offered in-class assistance. Case studies 1 and 2 both describe the lack of involvement of Paul, Faith and Marg in teaching students with the technology. A clear example was provided in Case study 1: "[Roger] seems to be focusing on students doing 3D design while Paul takes the rest of the class" (Researcher observations, 25 September 2017). Faith's comments describe how her and Marg's students were taught in a session by others: "[Roger] and [Paul] did the whole, 'this is our first lesson on 3D design software', the run through" (Faith, interview, 5 December 2017). Both of these comments relate to how the PBL students from Marg and Faith's class and Paul and Roger's class were introduced to the technology in their lessons.

Thus, in respect of this discussion point regarding team teaching and any impact it may have on how the SDLs influence teachers, it could be said that there were certain affordances that team teaching provided for some teachers, especially when the technology was first being introduced to the students. Certain teachers were able to distance themselves to a large extent from integrating technology as they could rely on their team-teaching partner, in respect of Paul, or their PBL teaching group to support them, in the case of Marg and Faith. There were implications for these teachers due to their lack of involvement in the integration of technology into their classrooms at this stage. These were described in Section 6.1.(The issue of mentorship for newcomers working with SDLs; Developments in newcomers' technology-

integrated practice and the role of the SDLs), where it was shown how TPK was not developed by these teachers.

There were also effects on teachers' practice due to lack of involvement when the technology was introduced to the PBL students. My observations of the session involving Paul, Roger and the SDLs cited in previous paragraphs in this section highlighted how Paul concerned himself with the behaviour management of the students. Hence, he was not involved in developing his practice using technology. The same lack of development can be assumed at that point in teaching for Marg and Faith as they were not physically present in the classroom.

Further PBL lessons involving Paul did not reveal anything to challenge the idea that he was largely removed from teaching with technology as he seemed to continue in his role, assisting with behaviour management and general classroom management. Students who returned to Marg and Faith's class were assisted with technology by the SDLs, not by the teachers. An example of how the teachers viewed their involvement was offered by Marg in referring to the SDLs' in-class assistance: "It was more them taking the lead of actually supporting the students rather than involving us" (Marg, interview, 5 December 2017). As discussed in Section 6.2, Marg and Faith had the SDLs assist their students after Paul and Roger introduced the technology to them. This effectively removed Marg and Faith from developing practice around the teaching of technology in their PBL classes.

Hence, the point being made here is that the provision of team teaching gave some teachers the opportunity to lessen their involvement with the SDLs, which seemed to reduce any effect the SDLs could have on their knowledge and practice. Choosing not to attend the pedagogical discussion session and engage with the SDLs saw some teachers limiting the capacity for the SDLs to influence their TPK. Similarly, team teaching provided opportunities for the teachers to opt out of teaching with the technology. Other teachers could effectively substitute for them in roles concerned with implementing technology, which limited the

SDLs' influences on their practice.

Conversely, there were teachers who chose to work closely with the SDLs, engaging with them in the integration of technology for teaching the PBL classes. Emma, in Case study 3, described how she was influenced by the SDLs in her one-to-one pedagogical discussion session, for example, "seeing the SDLs' confidence with the software, gave me confidence … as to how students will use the software" (Emma, interview, 6 December 2017). This indicates Emma's development of TK. However, it also links to development of TPK: gaining a deeper understanding of how students use technology influences approaches to learning which could then affect her teaching. Finn described how the SDLs influenced him in the software training and pedagogical sessions: "The SDLs were able to skill us teachers up meant that we then had the skills to help the students" (Finn, interview, 8 December 2017). This indicates that he saw the SDLs as having influence on both the teachers' knowledge and practice. However, as Finn did not go on to have the SDLs in their classroom due to logistical issues, any effects of his working in a teaching team with the SDLs was not observed.

Roger and Tom, in Case studies 1 and 3 respectively, were very heavily involved in integrating technology and working with the SDLs. This was evident in both the pedagogical discussion session and during in-class assistance. How Roger viewed his and the SDLs' roles can be seen in this comment: "My job was to say, to provide a bit of framework about what was happening and his job was to let him put things in and say, you know, test out the ideas" (Roger, interview, 5 December 2017). Tom saw the SDLs as "someone who is going to help [me] to build on [my] professional practice" (Tom, interview, 29 November 2017). Both Roger and Tom's comments support previous discussion points where it has been shown how mutual engagement and development of a joint enterprise can be seen between these teachers and the SDLs.

Whether team teaching had any effect on the ability of Finn, Roger and Tom to take on these roles and work closely with the SDLs is difficult to say. In other words, it cannot be said

with any certainty that being in PBL teams and having the support of a teaching group provided these teachers with a greater opportunity to develop their knowledge and practice in respect of technology integration. It could be argued that they would have engaged with the SDLs to the same extent and developed the same degree of knowledge and practice if they worked independently. To prove this would require comparisons to be made, which is beyond the scope of this research. However, it could be said that without having the support of another teacher in a team-teaching structure, behaviour and classroom management would have likely been the focus of Finn, Roger and Tom in their classrooms during this study. Hence, there is a question mark as to how much time and attention these teachers would have been able to devote to integrating technology if they were the only teacher in the class.

As regards TK and TPK gained from engaging with the SDLs in the software training and pedagogical discussion sessions, it could be foreseen that they could have been developed to the same extent without team-teaching structures being in place. However, it should also be pointed out that if the teachers were not in teams, there is an argument that each of them may have been more likely to have engaged in the pedagogical discussion session. However, again, proving that is beyond the scope of this research.

To summarise what has been discussed in this section, evidence of links between the affordances that team teaching provided for the degree of involvement teachers had in engaging with the SDLs has been provided. Some of these links were stronger than others. Notably, the way certain teachers (Marg, Faith and Paul) were able to utilise teaching-team and group structures to distance themselves from integrating technology, meant their involvement with the SDLs was limited. This, in turn, meant they could not be influenced by the SDLs to develop their TPK or practice in integrating technology in their classrooms. Tom and Emma both engaged with the SDLs prior to and during the class. Hence, there was little from their case study to signify any influences from team teaching. However, the same cannot be said of Paul and Roger. They organised their teaching team, with Paul taking on a behaviour management role, leaving Roger to focus on integration of technology and work

with the SDLs. The way they organised their practice and the roles they were able to take as they worked together in a team is an example of how team teaching can be a factor in answering the research question. How Paul and Roger operated suggests that team teaching can allow a teacher to invest heavily in developing their knowledge and practice in respect of integrating technology while the teaching partner covers other aspects of typical teacher practice such as behaviour management. As the focus here is on the SDLs working with teachers to influence knowledge and practice on integrating technology, a teacher who takes on the role of focusing on technology will have greater opportunities to develop mutual engagement and a joint enterprise with the SDLs. This is then more likely to lead to these teachers having their knowledge and practice influenced.

This section has provided discussion on teaching teams, groups and individual teachers taking different approaches to teaching with technology in their PBL classes. Although not discussed both in this sections and elsewhere in this thesis, there have been suggestions that contextual factors were also relevant. This is the focus of the next discussion point.

9.6. The significance of the amount of time provided for SDLs to work with teachers

For this discussion point, there is a focus on the involvement of SDLs throughout the study and the amount of time provided for them to work with the teachers. Issues relating to time have been alluded to in the teacher quotes, but there have not been discussions until this point on any possible role this could have had in how the SDLs influenced the teachers' knowledge and practice. This section highlights how the SDLs were set up to work with the teachers. It concentrates on the amount of time that was provided for the three sessions in the study but also opportunities in between sessions, particularly in advance of in-class assistance. Some teachers viewed limits on time spent with the SDLs as a hindrance to establishing relationships and developing mutual engagement and a joint enterprise. This, then, reduces the amount of influence the SDLs can have on the teachers' knowledge and

practice.

The SDLs were involved with the teachers in three sessions as part of this study. The first two of these sessions had designated and time-restricted slots of professional learning. The third session, in-class assistance, was entirely at the teachers' discretion and for the length of time they desired. However, even with the choice in respect of in-class assistance, there were limitations on time, given that the PBL lessons had specific time limits, as one would expect in timetabled school classes. Hence, there were restrictions on the amount of time the SDLs were involved with the teachers throughout the study.

The reflective interviews revealed that all teachers referred to how an increase in time spent with the SDLs could have been a factor in the degree of influence the SDLs had on their knowledge and practice. Faith talked about how more time with the SDLs in preparing for their providing in-class assistance and working with her students would have been a benefit to her:

> I would have loved to have sit down with them even if it was for 10 or 15 minutes and talk about "What are things you can help my students with? What is it you can offer? What skills? What can you improve on their work? That I necessarily don't know". (Faith, interview, 5 December 2017)

This highlights how she felt there needed more structure and planning time between her teaching team and the SDLs in advance of their involvement with their PBL class. However, it should also be noted that there were other contextual factors described in Case study 2, notably the rushed start to the lesson. Without such a start, some of this preparation time could have been achieved. What is relevant for this discussion point is that in the context of Faith and Marg's PBL lesson, restricted time meant she felt a lack of knowledge of what the SDLs could offer, what their role was. This suggests limits to the SDLs influencing her knowledge but also her practice. Gaining a better understanding of what the SDLs were doing with her PBL students would have likely added to her TK and her TPK if she learned from the SDLs how they engaged the students with technology. This could then have led to

changes in her practice.

The views of the deputy principal were closely linked to those expressed by Faith above:

> [I] would like to see if a staff member was able to reflect deeply and have that time because it takes time to break down to see what were those students doing that made it effective for me as a learner, then I can adopt that in terms of my own pedagogy in class. When they were working with students, I wonder if they were given enough time to think about that and break it down and whether if that happened, we would see some evidence then. (Deputy principal, interview, 8 December 2017)

Although she stated that her comments were not inspired by the observations made during this study, rather more from personal knowledge of professional learning, they highlight that she saw a link between time with the SDLs and the advancement in teacher's knowledge. It is not exactly clear the type of knowledge the deputy principal was referring to in her comments. She could have been talking about TK or TPK, but it is clear that she saw worth in there being time allocation for reflection and distillation by the teacher as to how the SDLs were influencing their knowledge and perhaps their practice.

Roger did not provide comments that directly mentioned issues with time restrictions. Instead, he mused over what could have been achieved if he had been able to have more time with the SDLs. He imagined that he "could have little sessions with SDLs early on" if he were to have been given more time (Roger, interview, 5 December 2017). Roger's comments suggest that he saw value in being given more time and that having this would improve the provision for his students, in other words, his practice. Finn did not go on to have the SDLs provide in-class assistance but commented positively on the idea of pre-lesson planning meetings with the SDLs: "I would have done that anyway if he had had them in his lesson" (Finn, interview, 8 December 2017). Finn's comments highlight the importance of spending time with the SDLs before they provide in-class assistance.

In contrast to Faith and in some ways putting into practice what Roger imagined and Finn said he would have done, Tom ensured that he had preparation time with the SDLs. In Case study 3, he was observed discussing roles, planning and foreseeing how the SDLs could best

have an impact on his PBL students in advance of their involvement with his class. However, despite having spent time with the SDLs in advance of in-class assistance, Tom still saw issues with time restrictions and boundaries to developing a stronger enterprise and mutual engagement: "Over time, boundaries relax, certain things become embedded and they develop their own intimacy … with the amount of time, particularly with these SDLs, I haven't had enough time to do that. (Tom, interview, 29 November 2017). His views illustrate that he believed that greater time with the SDLs would produce closer working relationships, enhancing opportunities for the SDLs to influence teachers' knowledge and practice.

I shared the situation observed with Marg and Faith's restricted time in preparing for the SDLs' in-class assistance and Tom's comments on time with the principal. Her response was, "Then we have to give more time" (Principal, interview, 11 December 2017). This suggests she recognised that the influence of the SDLs could affected by restructuring the time allocated for involvement with the teachers and/or the sessions in the strategy. In other words, time could have been provided for all teachers to prepare for in-class assistance in a similar way that Tom organised himself and the SDLs. Her views reinforce the idea that time was a factor in respect of the SDLs being involved in assisting teachers in the classroom, and limits on time affected the degree to which the SDLs could influence the teachers' knowledge and practice in this regard.

Emma highlighted a desire for greater time in respect of learning how to use the software, saying that this could have allowed for "shared ideas while having a play" for teachers during the software training session (Emma, interview, 6 December 2017). Her comments suggest a link between greater engagement of the teachers in developing their knowledge and the use of technology and the time to facilitate this. Marg focused on how she saw benefits of having time to spend with the SDLs in the classroom: "I was 100% confident in their knowledge and ability to be able to support students. Definitely, I would have liked to have spent more time with them doing that" (Marg, interview, 5 December 2017). This relates to the context of Marg and Faith's PBL class described in Section 9.5 and the demands of such issues as

behaviour management for the teachers. Having such demands affected the teacher's ability to spend time with the SDLs and being mutually engaged in providing assistance to students in the class integrating technology.

Paul's comments on time related to his developing a greater shared repertoire with the SDLs: "If I'd spent some more time with them, I'm sure there would have been some language I would have taken from them" (Paul, interview, 6 December 2017). His comments on how limits on time led to limits on developing CoP dimensions of practice with the SDLs seem to echo those of his peers. However, as with Marg's comments above, there were other factors rather than just time that played a part in his developing a shared repertoire with the SDLs, notably his decision to focus on other aspects of his practice. His lack of involvement with the SDLs beyond the software training session discussed in Section 9.1 played a part in this.

In summary, what has been discussed here highlights that all teachers saw the significance of time on the degree to which the SDLs could influence their knowledge and practice. The majority of the teachers referred to time issues around the SDLs providing in-class assistance and how the SDL strategy limited preparation time between teachers and SDLs. The knock-on effects are reductions of the amount of influence SDLs can have on teachers' knowledge and practice. However, there were other areas of the SDL strategy used in this study seen by some teachers as affected by time constraints, such as more time to provide software training, suggesting there are other ways that TK and TPK can be better developed by teachers working with the SDLs. In a different context, there could be different time allocations. These could be greater or lesser amounts of time for SDLs and teachers to work together. Such variances could lead to changes in the degree of influence on teachers' knowledge and practice.

9.7. The significance of context

In this discussion point, the focus is on how important contextual and organisational

aspects, such as school culture and student voice can positively influence the way teachers and SDLs collaborate. This is then discussed in respect of the TPACK upgrade to include contextual knowledge (XK) proposed by Mishra (2019).

Details of how this research was carried out in a school with a culture promoting student voice and a drive to have students empowered in a variety of roles with technology can be seen illustrated in Figure 4. The views of the Principal in seeing the school's professional learning culture as, "fostering genuine student voice" (Principal, personal communication, 2016) and the discussions provided in pages 99 to 105, highlight the role that student autonomy had in attempts to improve teaching practice in this school. These pages also outline the vision of the school to have teachers that innovate and are passionate, who focus on quality teaching and learning using digital technologies and that these are featured in the schools 3 year, "Site Improvement Plan" (Principal, personal communication, 2016).

The case studies show Tom, Emma and Finn referring directly to the school's culture and student voice. Tom could be seen aligning himself, showing a, "belonging" (Wenger, 1998, p. 179) to the school's culture of empowering students when he referred to having, "trust levels [that] are going to raise to meet…expectations" (Tom, interview, 29 November 2017). He also referred to perceiving that there were levels of trust based on the culture of the school and the experiences he had in professional learning at the school. Furthermore, Tom stated that he was fully aware of the importance of the culture, stating that he knew, "what the expectation is here as we have done it a few times" (Tom, interview, 29 November 2017).

Emma also displayed similar alignment to what Tom had shown, outlining how, "it's important for us to hear their voice" (Emma, interview, 6 December 2017) where the "us" were the teachers and "their" were the SDLs. She also went out of her way to arrange a one-to-one session with SDLs as she could not make the scheduled session. This suggests that she saw not only the benefits of working with the SDLs and how they could improve her capacity to integrate technology but also how much she recognised the significance of the school's

culture in respect of student voice.

Finn recognised not only personal benefits but also the effects on his peers in working with the SDLs. He described the "positivity" (Finn, interview, 8 December 2017) that having sessions with the SDLs brought to the teachers, their mutual engagement and greater "excitement" (Finn, interview, 8 December 2017) compared to similar professional learning he had led. The main underlying reasons Finn gave for these positive feelings amongst his peers, were firstly pride in the SDLs and a desire to "support" (Finn, interview, 8 December 2017) their endeavours. Secondly, Finn recognised that the teachers and the SDLs collaborated in an environment that was conducive to learning from and with each other. Open discussion and idea sharing were essential elements of their professional learning. He saw that there was a culture promoting the idea that SDLs had both experience and knowledge to share with the teachers. All of Finn's comments suggest that the culture of the student voice in the school was embraced by the teachers involved with the SDLs. There was a sense that teachers could see the significance of having students in these roles and that influenced their response to opportunities for professional learning and potential school improvement.

Paul and Roger made comments which showed indirectly their awareness of the school culture in respect of being a learning community that the SDLs should play a greater part in improving. Paul talked about the DLs playing a greater role in the school community alongside teachers. Roger referred to sustainable approaches to furthering student agency and students working with teachers. Their comments suggest that what can be seen from the views and actions of Tom, Emma and Finn are responses to opportunities that have been provided by the schools approach and the culture that has been fostered. This culture of student voice and collaboration with students influences the teachers responses to the professional learning provided with the SDLs. In other words, there are significant contextual and organisational aspects of the school that influence how these teachers respond to the opportunities provided. Promoting a culture where student voice is a major factor in teacher

and school improvement seems to influence the mindset and actions of teachers in this research study.

This discussion point seems to support issues discussed about the significance of XK by Mishra (2019). That paper called for greater recognition and research that involves teacher awareness and actions given the contextual knowledge they have in the environment they are working in, even going so far as to say that this form of knowledge is, “of critical importance to teachers” (Mishra, 2019, p. 77). Of course it is very difficult to say what would have occurred if there was no influence from the way the school was organised in respect of actively promoting and involving students in technology integration, working with teachers, as part of the school improvement plan. However, what is clear is that the teachers in this case study, recognised the influence of these contextual factors. They had knowledge of them (XK) and this seemed to influence their attitudes and actions in collaborating with SDLs in trying to integrate technology.

Chapter 10: Conclusion

This research project arose from personal experiences in middle and senior school leadership roles with responsibility for aspects of digital technology integration in the United Kingdom and Australia. These roles provided me with an opportunity to see, first-hand, the difficulties in trying to realise sustainable development in teachers' technological knowledge and practice. Having spent 18 years working in schools, I have also realised that knowing how to use different digital tools effectively, how to teach others how to use them and develop practice that effectively assists students to learn skills using technology may not necessarily come from teachers or professional trainers. The rise in popularity of student autonomy and student leadership has encouraged me to pursue personal interests in providing opportunities for students to assist in technology integration in their school. Through developing and running SDL schemes in schools, I began to see possibilities in influencing teachers' technological knowledge and practice. These personal experiences led to a desire to explore the effects that SDLs can have on teachers and technology integration in schools.

A review of literature examining technology integration showed that, despite investing financially in technology and professional learning for teachers in many countries and approaching the problem with a variety of solutions, issues remain. Examples include how best to approach teacher professional learning, particularly where teachers have different levels of confidence and skills, as well as ensuring that teachers' use of technology relates to shifts in pedagogy. These issues are part of the problems faced across education in establishing a consensus on the most effective strategies for achieving systematic educational technology integration in educational settings (Harris, 2005; Hart, 2007; Lindberg et al., 2017).

There are a few studies that feature students in leadership roles in education settings being given the opportunity to influence the knowledge and practice of teachers trying to integrate technology (Chuang, 2006; Corso & Devine, 2013; Martinez, 2007; Martinez, 2008; Passey,

2013, 2014; Peterson, 2012). However, very few of these are in peer-reviewed journals, and none of them look at how teachers were influenced by students. In peer-reviewed research using a TPACK lens that talks about students influencing teachers who are using technology in their classroom (Di Blas et al., 2014; Di Blas & Paolini, 2017; Di Blas, Paolini, et al., 2014; Jones et al., 2015), student influence was often unplanned, not the primary focus of the research or in university settings. As discussed in Section 2.1. (Knowledge development in TPACK), a literature search highlighted that there have not been any studies undertaken that specifically examine what happens when students are trained and put in active roles to influence teachers' knowledge and practice in a secondary school setting.

Reviewing literature on the influences of teachers' knowledge in respect of education technology highlighted the use of the TPACK framework (Mishra & Koehler, 2006). At the time of writing, there have been 1418 articles, 318 books and 438 that use TPACK as a measure of teachers' knowledge**.** However, TPACK merely provides a lens which can be used to understand changes to the knowledge of teachers when using technology. Being able to consider changes in teachers' knowledge and practice when working with the SDLs offered an insight into the influence SDLs may have on teachers. At the outset of the research, this seemed to be the focus for understanding what happens when SDLs work with teachers; however, the study developed to show that an understanding of how any influence SDLs have on teachers was also vital. Such understandings provided explanations for why the knowledge and practice of certain teachers are influenced while those of others are not, and the circumstances that seem to lead to such shaping.

As this study sought to have students become SDLs and then be in positions to potentially influence teachers' knowledge and practice in the same school, careful analysis of the relationships between those involved was necessary. It is also important to recognise that this was a small-scale study set in a particular context. There were specific structures in which the SDL program was implemented that involved team teaching and teachers learning how to teach PBL, often with little or no experience of such an approach. To better understand this

complex context, a CoP lens (Wenger, 1998) was used alongside the TPACK framework. With both CoP and TPACK framings, teachers' knowledge and practice could be examined from the perspective of seeing learning as a transformative experience over time. In other words, this research focused on a study of what happens to teachers when they work with SDLs to integrate technology in their practice, and if these teachers are influenced by the SDLs, how that happens. This was encapsulated in one research question: *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?*

This research was based in one secondary school with a group of teachers preparing and teaching a specific course using specialist digital technology. The SDLs were a group of students from the same school, trained and provided opportunities to work with the teachers. There were also other contextual factors driven by the senior leaders of the school impacting on this research, such as a culture of improving student autonomy and the introduction of a PBL approach. According to Rashid et al. (2019), "qualitative case study methodology enables researchers to conduct an in-depth exploration of intricate phenomena within some specific context" (p. 1). Thus, a qualitative case study was considered the most appropriate methodology.

However, the specificity and contextual factors highlighted in the previous paragraph also reveal the limitations of this study. There were only seven participating teachers working in a specialised environment. This limits the generalisability of the findings. It was meant to be, and remains, exploratory in nature with the use of triangulation techniques to ensure the robustness of the findings, as discussed by Flyvbjerg (2006) and Yin (2003, 2009). The findings are intended to be contextualised and provide a platform for further research into the different ways that students in active roles in educational settings can influence teachers' knowledge and practice.

10.1. Propositions

To answer the research question posed in this study, five propositions are offered from the findings:

1. **SDLs in peripheral and more liminal positions can influence teachers' knowledge and practice.**

This proposition relates to discussion points 9.1 and 9.2 as it makes propositions based on discussions around peripheral positions, boundaries and SDLs in brokering roles. This is not meant in any way to detract from the value of key findings related to shifting boundaries in CoPs and the implications of SDLs as brokers. The decision to combine the two discussion points into one proposition merely represents the way these issues are intertwined from which proposals for can be made.

Teachers throughout this research talked about issues they had in being able to fully trust the SDLs, to see them as equals in an equivalent professional capacity to their role as teachers. Having these boundaries in place meant that the SDLs worked largely from peripheral positions. However, there were specific situations and conditions where these boundaries shifted, seemingly becoming more permeable. This occurred when the SDLs provided in-class assistance and the teachers' attention was drawn to other areas of classroom practice, such as behaviour management.

The significance of the shifting of boundaries in CoPs that involved the teachers and SDLs lay in the way it altered conditions for the teachers and SDLs to work with students and work with each other in the classroom. With these more flexible boundaries in place, the SDLs were observed working for a limited amount of time with students in the class on a one-to-one basis. They were also seen in the cases involving Tom, Roger, Marg and Faith providing insights to the teachers on what they had done while working with the students, how the students were progressing and the learning of the students using the technology. In other words, there was, in these two cases, a greater sharing of practice and of accountability as

well as developments in a shared enterprise between the teachers and the SDLs while the boundaries shifted. As such, these shifts in the boundaries provided greater opportunities for the SDLs to influence the teachers' practice when integrating technology.

It could be argued that if other parties took on similar roles to those of the SDLs, for example, other teachers or trainers rather than students in SDL roles, they may have influenced teachers in the same way as described in the previous paragraph. However, there are three aspects of having students as SDLs in these roles that are worth noting from this study. The first aspect relates to the SDLs being students. The teachers recognised the SDLs could offer different perspectives from those of their peers or adult trainers. As the SDLs were part of the student body in the school, they had identities and practice that were seen as different from those of the teachers or of adult professionals. The teachers recognised and appreciated that the SDLs were able to imagine how the PBL students would react to the technology as well as the teaching approaches that they would most likely find effective to enable them to learn the necessary digital skills.

The second aspect relates to the fact that the SDLs were given experiences in training and teaching other students prior to the study, enabling their understanding of teacher practice. The SDLs then shared these forms of knowledge and experiences with the teachers during the specialist sessions focusing on software training and pedagogy to assist them in preparations to teach with technology. Subsequently, the SDLs assisted in classrooms, supporting the teachers as they attempted to integrate the technology in their practice.

The third aspect relates to the fact that the SDLs had prior experiences to prepare themselves for their roles working with the teachers and also often worked with more than one group of teachers during the study implementation. The structure of the professional learning meant that the SDLs did not provide in-class assistance as their first experience of working with the teachers. In-class assistance was, for the SDLs, their third involvement with the teachers. This gave them insights into the ways of working teachers. More significantly,

however, was the way teachers such as Roger, Tom and Finn recognised how they could begin developing mutual engagement and enterprise with the SDLs prior to in-class assistance.

Hence, what is seen here seems to support the view that peripheries offer "multiple and diverse opportunities for learning" (Wenger, 1998, p. 118). The teachers were given opportunities to learn from the SDLs operating largely in peripheral positions in the teachers' CoPs. These opportunities for learning refer to the openings that teachers could use to enhance their knowledge and practice in respect of technology integration when working with the SDLs. In addition, as the professional learning involved the SDLs, the teachers were provided with opportunities to develop mutual engagement and enterprise around technology integration with students in specific roles and with specific experiences. This could be seen as unique opportunities for teacher professional learning.

This proposition also contributes new knowledge in respect of CoPs, as described by Wenger (1998), in two ways. First, there were shifting boundaries described in certain circumstances, where the SDLs seemed to move from the periphery to what can be described as more liminal positions. The permeable nature of the boundaries the teachers put in place for the SDLs granted them access to working with the students during in-class assistance, seemingly providing the SDLs with greater power in the classroom, more status and a more influential role. However, this was only temporary and, as made clear by the teachers at various points, the boundaries remained, keeping the SDLs on the periphery of the teachers' CoPs. Hence, the SDLs were not really centripetal in these CoPs. They could, however, be seen as being in more liminal positions than their regular peripheral positions. However, there are only two conditions, peripheral and centripetal described by Wenger. Such a binary view seems to contradict what was seen with the SDLs in this study.

Second, this study highlights specificity in terms of when boundaries were removed, which adds to the points made regarding shifting boundaries and peripherality by Wenger

(1998), discussed in Section 9.2. He claimed these areas of CoPs are ambiguous and difficult to understand. Boundaries are said to shift and flex, described by Wenger with a rather personal account as "elements of boundary would creep in to remind me that I was an outsider" (p. 120) relating to the claims processing environment much of the book is based on. However, there are no specific examples or conditions provided by Wenger that are said to lead to shifts, whereas in this study, it can be seen that shifts in boundaries occurred when the teachers dealt with other matters in the classroom and the SDLs provided in-class assistance by working largely independently. These add to the knowledge regarding boundaries and peripheries in an educational context.

2. SDLs can influence teachers' TPK, not just their TK.

In research where students have been seen to impact the ability of teachers to integrate technology in their classroom (Di Blas et al., 2014; Di Blas & Paolini, 2017; Di Blas, Paolini, et al., 2014), the focus has been predominantly on teachers' TK. Findings in this research study, similarly, highlighted the effectiveness of students in SDL roles for training staff with varying degrees of confidence and skills in how to use a specific software tool. All the teachers involved in the study recognised the positive influence the SDLs had on their TK. However, in contrast to previous research, the SDLs not only influenced teachers' TK but also they were highly influential in terms of TPK, offering insights on how best to introduce the technology, together with suggestions as to how to approach teaching the key skills, engaging students in using the technology and various aspects around effective technology integration when deploying the software. The SDLs' capacity to influence TPK as well as TK was determined in this situated study by two key factors:

- The teachers were provided periods of planning with the SDLs with a specific focus on pedagogical approaches to teaching with technology. The SDL strategy was organised to involve a pedagogical discussion session as one of the three ways the SDLs worked with the teachers. This designated time provided teachers with

opportunities to discuss approaches to teaching with the technology. They could and were seen to ask questions, garner opinion and be influenced by the SDLs on relevant pedagogy in preparation for integrating the technology.

- There was a culture in the school to develop student autonomy and encourage open sharing. This was driven by the senior leaders, and it is worth a reminder that I was also one of the senior leaders and researcher in this study. As such, I should be acknowledged as part of this culture. Evidence shows that this culture was directly influential in the way some teachers aligned themselves to working with the SDLs, knowing that was part of the ethos of the school. Evidence also shows that it was indirectly influential in providing confidence for the teachers to involve themselves in the SDL strategy, knowing that this was part of the culture in the school to develop greater student autonomy and embrace new ideas.

3. Both teachers' trajectories and their alignments can be key factors in the degree to which SDLs influence their knowledge and practice.

Wenger (1998) described identity formation as evolving continually when members participate in a CoP. He referred to the concept of trajectories as being how individuals "incorporate the past and the future in the very process of negotiating the present" (p. 154). Hence, there may be events from the teachers' pasts as well as how and where they view themselves in the future in the various CoPs they are involved in at the school that affected their actions during this research. Alignment has "the ability to coordinate perspectives and actions in order to direct energies to a common purpose" (Wenger, 1998, p. 186). Hence, it is also an identity trait that can affect teachers' actions, where some teachers align themselves with the enterprise of the school in respect of the involvement of the SDLs, and this affects their practice.

This research study featured teachers with a variety of teaching experience, experience at the school and experience in respect of integrating technology in their practice. The software offered a variety of challenges to the teachers involved, meaning some struggled to develop

the skills required to integrate the technology into their classrooms. Despite numbering only seven, the teachers had a breadth of skills, knowledge and confidence in integrating technology.

Results from the pre-involvement survey (Table 3) gave an insight into their self-confidence, their perceived skill levels and how they viewed the opportunity to work with the SDLs. The responses then informed questions asked in the reflective interviews, offering deeper insight into the teachers' identities and the factors that influenced how they developed TPACK during the study. The responses to those questions highlighted the significance that particular elements of the teachers' identities played in how they worked with the SDLs and the degree to which they involved or removed themselves from influence. Unsurprisingly, these factors also affected the degree of influence the SDLs could have on teachers' knowledge and practice. In particular:

- A teacher's trajectory influences their involvement in the integration of technology and the degree to which they mutually engage and develop a joint enterprise with the SDLs when a SDL strategy is introduced. This is seen in the form of:
    - Past trajectories, where teachers' previous experiences with technology, particularly where they had been negative, appeared to affect teachers' willingness to engage with the SDLs. This could be seen with Marg and Faith, who struggled with grasping the fundamentals of the technology, revealing they had issues when previously learning how to use technology. After having SDL support in the software training session, both teachers found it challenging to continue to develop their digital skills without the support of the SDLs. They then largely removed themselves from integrating technology, relying on the SDLs and Roger to provide that role with their students.
    - Future trajectories, where teachers recognise that engaging with the SDLs is significant to developing their own practice and negotiating an enterprise with SDLs enhances the teaching in their classroom. This could be seen with Roger

and Tom. In contrast, future trajectories can also lead teachers to remove themselves from engaging with the SDLs to focus on developing their CoP positions in the school, as was seen with Paul and to some degree with Marg and Faith.

- Tom and Emma highlighted how being aligned to the culture and ethos of the school encouraged them to trust SDLs to the degree that they sought their opinions and advice and had the SDLs influence their practice. These factors affect the degree of influence the SDLs could have on the teachers' knowledge and practice. The teachers who recognised the role that the SDLs played in promoting student autonomy and aligned with the culture of the school to develop stronger relationships with the students were seen to be greatly influenced by the SDLs.

The extent and the way that teachers worked with SDLs in this study were heavily influenced by these specific aspects of their identity. Some teachers provided evidence of how either their trajectories or their alignment influenced working with the SDLs. However, other teachers highlighted how both of these were factors.

4. Team-teaching structures provide opportunities for teachers to act on particular aspects of their identities. This affects how they develop joint enterprise with SDLs around technology integration.

Team teaching can facilitate specific and specialist roles in classrooms, where a teacher can focus on a single area or a few knowing that the other member of their team may take on areas they do not focus on. The choice of where a teacher focuses their attention, and indeed whether that means being heavily involved with technology integration or not, can be linked to aspects of their identity, such as trajectories, as already discussed. Without a team-teaching approach, a sole teacher may not have the same opportunities to decide on involvement or lack of involvement in specific areas of practice, given the typical demands of classroom practice. For example, it is difficult to envisage a situation where a teacher working on their

own in a class would be able to largely absolve themself from behaviour management responsibilities of the students in their care. However, team teaching enabled this to happen in the study.

Hence, having team-teaching structures was seen to both encourage teacher involvement with the SDLs for some teachers and to offer ways for other teachers to opt out from integrating technology and, to a large extent, not be involved with or influenced by the SDLs. Evidence from the case studies shows that the particular option teachers chose was dependent on aspects of their identity. Tom, Roger and Emma described past experiences which influenced their trajectories, giving them opportunities to see how working with students in active roles could enhance their own knowledge and practice. Roger, Emma and Finn referred to characteristics of alignment which encouraged their engagement with the SDLs. As regards those teachers who chose to largely opt out, Marg and Faith talked about the issues they had in grasping the necessary technology and their lack of confidence. They linked these to past experiences negatively affecting their trajectories. Paul highlighted that he was concentrating his efforts on developing relationships with the students in the PBL class and that this linked to his future trajectories in the school.

A team-teaching approach also facilitated opportunities to invest time in specific areas of practice. This proposition does not discuss the significance of time in terms of how influential that factor is in developing levels of mutual engagement and joint enterprise between teachers and SDLs. This was the focus of discussion point 9.6 and is the subject of the next proposition. Instead, the proposition in this respect relates to how this study shows that having team-teaching structures provides more time for teachers to act on particular aspects of their identities. This study highlighted ways in which particular teachers working in teams, such as Roger and Tom, were provided opportunities within the team structure to invest time working with the SDLs. This saw these teachers both focusing on preparing for the in-class assistance of the SDLs and working closely with the SDLs in their classrooms. Being part of team-teaching structures gave them the time that a sole teacher is highly unlikely to have enjoyed.

However, as with specific and specialist roles, the same provisions can also enable teachers to invest time away from being involved with the SDLs.

Hence, there are implications from team-teaching structures in respect of teachers developing TPACK. The specialisation that teachers choose can be linked to aspects of their identities. Team-teaching structures provide more than one teacher in a team. These enable some teachers to not engage with the SDLs and develop their TPACK, while others develop mutual engagement and a joint enterprise, which can impact their TPACK.

5. The influence of SDLs on teachers' practice is closely linked to the amount of time teachers have to develop levels of mutual engagement and joint enterprise between themselves and SDLs.

The seven teachers in this research study engaged with the SDLs in a variety of ways and amount of time. All of them were involved in the software training session. Some teachers, such as Marg, Faith and Paul, did not participate in the pedagogical discussion session. Finn did not have the SDLs provide in-class assistance for his PBL class. Paul did not work with the SDLs when they provided in-class assistance to his PBL class. Marg and Faith largely left the SDLs to work alone with their students during in-class assistance. Roger and Tom spent the largest amount of time with the SDLs over the whole program, and their comments reveal high levels of enterprise and mutual engagement in the process of involving the SDLs in helping develop technology skills in their PBL students.

Both Roger and Tom had some degree of preparatory time in advance of the in-class assistance. This was not organised as part of the SDL strategy and, in the case of Roger, seemingly impromptu in nature. Observations were made of short discussions and clarifying comments regarding what was expected to happen and what the roles of the SDLs and the teachers were. However, the fact these two teachers had some degree of preparatory time with the SDLs facilitated greater engagement in the process and further developed a joint enterprise between themselves and the SDLs. It could be seen in the depth of conversation

from both parties and how, for example, minute details such as where best to stand in the classroom were thought through.

These preparatory sessions came after the pedagogical discussion sessions where the same two teachers, Roger and Tom, were also heavily involved in teasing out the opinions of the SDLs on the best approaches to teaching with the technology. Hence, both Roger and Tom were developing their enterprise and showing considerable engagement from the early stages of the SDL strategy. In those same pedagogical discussion sessions, Finn was also very involved with the SDLs. However, he did not follow this up with having the SDLs provide in-class assistance; so, despite some levels of mutual engagement and joint enterprise being developed, they were not at the same extent as Roger and Tom. In addition, as already referred to in the opening paragraph, some teachers did not attend this session and thus did not demonstrate development in mutual engagement and joint enterprise with the SDLs.

During the in-class assistance phase of the SDL strategy, both Roger and Tom involved themselves with the SDLs the most of all the teachers in this research study. They were observed in discussions with the SDLs during the classes and afterwards. They revealed that these interactions were based on learning from the SDLs about what they had covered with their PBL students, the progress of the students and about the success or struggles the SDLs were having when assisting their students. Again, this highlights a degree of intensity in the enterprise of integrating technology shared with the SDLs. It also highlights the significance of time. Those teachers who spent more time than others with SDLs, for example, Tom and Roger compared to Paul, developed more of what they referred to as trust in the SDLs. However, using a CoP lens, it can be seen that references to trust actually relate to mutual engagement and joint enterprise. It is the idea that identities are formed in CoPs through "layering of events of participation and reification" (Wenger, 1998, p. 151), and the SDLs who participate more frequently or for greater lengths of times have the chance to increase such layers over time.

Looking at this through a TPACK lens, time can be seen as a contextual factor. Many teachers in the study referred to being constrained by time and how this impeded their ability to spend more time with the SDLs. Time issues are unique contextual factors in schools, with the demands of timetables and the requirement to be present in classrooms with the students. This leads to restrictions on the time that teachers can commit to SDL strategies and to the development of mutual engagement and joint enterprise with the SDLs.

Thus, by using a TPACK lens and a CoP lens, the factors of time, mutual engagement and joint enterprise can be linked to both teacher knowledge and teacher practice. Teachers who spend more time with SDLs can build deeper engagement and develop an enterprise which would impact a teacher's knowledge. This could lead to the development of practice. When teachers invest time to work with SDLs providing in-class assistance, the focus is on practice in the classroom with some possible influences on teacher knowledge. Whether it is solely knowledge, solely practice or both being influenced, more time with the SDLs leads to greater influence for teachers.

6. The context that teachers work in and their knowledge of that context influences how they collaborate with SDLs providing factors that directly influence TPACK.

The school in which this research study occurred actively promoted and incorporated student voice and student action in both its plans for improvement and as part of teacher professional learning. There was clear evidence driven by senior leaders of an established culture that saw students working with teachers trying to improve teaching and learning in the school. The concept of SDLs was not new to the school and the extent of having students in these roles working with teachers integrating technology and on digital projects in the school community can be seen in Figure 4.

Teachers' comments in the case study reflect not only an awareness and understanding of the school's culture and the views of the senior leadership but, in some respects, an awareness of how that influenced them and their peers. This supports the points made by Mishra (2019)

regarding positioning context as a form of knowledge where the, "success of their efforts depends not as much on their knowledge of T, P, C and its overlaps, but rather on their knowledge of the context" (p. 77). Given this, teachers' knowledge of the context of their school in this research, plays a significant role in them developing TPACK.

However, Mishra (2019) says that adding XK as a form of knowledge to the TPACK diagram, "highlights the organisational and situational constraints that teachers work within" (p. 77). Evidence in this research study appears to challenge the wording used in this description where XK does not just relate to "constraints" but also relates to freedom, opportunities, affordances, influences and, maybe even, expectations that teachers work with. In other words, not only do contextual factors related to organisational structures and culture play an important role in teachers developing their TPACK but they are not necessarily factors that negatively affect TPACK. They can be positive influences.

The factors of context, time, mutual engagement and joint enterprise as well as all the other propositions described in this chapter seek to answer the research question: *How are teachers' knowledge and practice around the integration of technologies influenced by the introduction of student digital leaders?* While limited by the size and scope of the research as already detailed, these propositions along with the findings and discussion points from the case studies present a number of implications and recommendations for further research. These implications and recommendations relate to the involvement of SDLs in influencing teachers trying to integrate technology, wider implications for teacher professional learning as well as theoretical implications for CoP and TPACK.

10.2. Implications and recommendations for future research

The implications provided in this section are curated from the case study findings, discussion points and the above propositions. These are offered along with recommendations for future research:

1. **A more longitudinal study may position SDLs differently in CoPs with teachers, affecting how SDLs are able to influence teachers' knowledge and practice.**

The case studies and discussion points highlighted that SDLs operated largely from peripheral positions in CoPs involving teachers. Boundaries that prevented the SDLs from taking up more centripetal positions shifted, given certain teacher conditions. However, for the most part, the teachers were reluctant to remove the barriers they saw for establishing stronger relationships with the SDLs, continuously referring to an inability to trust the SDLs in certain situations or with certain responsibilities in respect of teaching and learning.

Several teachers in the research study commented on how, over time, they could establish stronger relationships with SDLs. They could be mutually engaged long enough to become proficient in a joint enterprise with the SDLs, developing a greater shared repertoire. This could lead to the SDLs having more centripetal positions in the CoPs with teachers, changing the role that the SDLs took and how they influence teachers' knowledge and practice. In a more longitudinal study, SDLs may have the opportunity to move from largely peripheral positions and acting in brokering roles to positions where they are on trajectories as newcomers aspiring for more experienced roles in CoPs with teachers. As newcomers, the SDLs could "provide new models for different ways of participating" (Wenger, 1998, p. 156), suggesting that the way they influence teachers' TPACK could be greater and/or different.

Thus, research into having students in SDL roles working with teachers trying to integrate technology over a longer period of time is recommended. It is worth recognising that any lengthening of time the SDLs work with teachers may mean the SDLs start at younger age, possibly resulting in greater trust issues for teachers working with younger students. Having said that, a more longitudinal approach, for example, over a whole school year, may provide opportunities for the SDLs to, firstly, establish stronger relationships with teachers who struggle with technology integration, building their confidence and upskilling them in these areas. Such an idea supports the suggestions made by teachers in this position wanting to have

more time and opportunities to work with the SDLs in this research study. Secondly, with more time, the SDLs may be provided opportunities to learn aspects of the curriculum involved. This could see them start to influence teachers in respect of TCK as well as TK and TPK.

2. The concept of distributed knowledge in TPACK involving students requires further research.

Research on distributed knowledge in TPACK is limited, especially where the focus is on students sharing knowledge with teachers. Papers reviewed in this study provide a brief insight into the possibilities for having knowledge held by students and shared with teachers, reducing the need for teachers to hold all the knowledge elements required to integrate technology successfully. However, papers are limited to studies on students showing teachers how to use software tools or providing technical assistance in a classroom situation when a teacher does not know how to get some aspect of technology to work (Di Blas & Paolini, 2017; Di Blas, Paolini, et al., 2014; Jones et al., 2015).

This research has illustrated how students in specialist roles as SDLs can be trained and upskilled so as to try to impact teachers in integrating technology in their classrooms. The aim of the study was not just for SDLs to influence TK, as seen in research on distributed TPACK. Teachers were provided with opportunities to understand students' perspectives and their advice based on their own experiences as well as the experiences of receiving classroom assistance with technology. The SDL strategy was structured to provide intentional sessions where TPK could be provided by the SDLs to teachers. During these sessions and at other points in the study, the SDLs were seen to influence teachers' TPK and TK.

This has implications for how distributed TPACK involving students is perceived. It extends the concept beyond merely TK and involves pedagogy. Thus, it is recommended that greater research on distributed TPACK be undertaken. This could involve students in similar SDL roles in different environments, such as in primary schools or in higher education, with a

larger group of teachers, where the teaching approach is not team teaching and with different approaches to the strategy used in this study. Conducting wider research as suggested will provide a greater understanding of the limitations and possibilities of involving students in SDL roles in technology integration.

This implication is not limited to research on distributed TPACK involving students. There is a lack of research on the role of student voice in TPACK more generally. Research is required that discusses engaging more directly with students in SDL roles or in any roles where they are able to provide insights and perspectives to complement those of teachers and school leaders. Student self-efficacy, collaboration, and agency should be central to future research with a focus on technology use impacting positively on learning and teaching.

3. **Having students who are experienced in teaching in SDL roles has implications for preparation in advance of SDLs working with teachers. Wider research is required to determine the significance of planning for the involvement of SDLs.**

The influence that SDLs were able to have on teachers' knowledge and practice in this study seemed to be enhanced by the SDLs having skills and experience in teaching with as well as in learning how to use the technology. However, this has implications for how SDLs gain experience, how they are trained and how they are provided time to work with their peers and with teachers.

This study featured SDLs who had a timetabled class and time to experiment with the technology, receive training on how to use it and learn how to develop projects using the skills they had learned. The class also provided time and opportunities for these SDLs to train and teach other students. This involved planning and evaluating approaches and sharing ideas and reflections on how they approached this. The SDLs then shared their experiences and modelled approaches they had used successfully, with teachers during this study.

Such an approach to professional learning seems to benefit from a considerable amount of planning and preparation time and resources before the SDL strategy commences. This has

implications for schools in terms of planning for the involvement of SDLs with teachers and suggests a more long-term approach. However, further research is needed to see whether students in SDL roles could influence teachers' knowledge and practice in the same or similar ways if they did not have the same preparation as seen in this study.

4. **Further research is required in different settings to determine the benefits of a multifaceted approach involving pedagogical discussion sessions, to professional learning for teachers trying to integrate technology.**

This study featured a SDL strategy that had three phases to it: a software training session, a pedagogical discussion session and in-class assistance from the SDLs to teachers trying to integrate technology in their classroom. It was also, in many ways, linked to the culture and ethos of the school, with the senior leaders espousing the benefits of student autonomy and student empowerment. This highlights some of the contextual factors in which this study was carried out, which may be different from further research in other schools. However, it also points to implications for how professional learning should be designed if it is to influence teachers' TPK as well as their TK.

The SDL strategy provided opportunities for teachers to be trained on how to use particular software. That, in many ways, provided just TK, although the comments of the teachers showed that the SDLs' approaches in that session also had some influence on their TPK. Through opportunities to discuss approaches to teaching with the technology in the pedagogical discussion session, the teachers involved were seen to have their TPK influenced. In-class assistance then provided opportunities for the SDLs to directly affect classroom practice.

There is a strong suggestion from this study that having the three different phases of professional learning, especially as it provided more than just software training, was important to the degree of influence the SDLs were able to have on teachers' knowledge and practice. This has implications for how professional learning could be structured if it involves

SDLs, in that opportunities should be provided for teachers and SDLs to plan possible pedagogical approaches in their classrooms and for SDLs to directly affect classroom practice. It could also be said that any professional learning that is trying to improve teachers' capacity to integrate technology, whether it involves SDLs, professional trainers or other teachers in the role of trainers, could benefit from being designed with these opportunities included.

Further research in different settings could provide results to compare with this case study, which is limited to one school with the aforementioned contextual factors. This could provide insights into the role that those factors played in the way the teachers engaged with the SDLs. Further research with different strategies and different delivery methods in the sessions, for example, more of a direct instruction rather a discussion session regarding pedagogy, would extend knowledge in this area. It could provide evidence on how significant particular approaches are on the SDLs' ability to influence teachers' knowledge and practice.

5. **Team-teaching structures in use in the context of this research study influenced the participation of teachers in classroom roles in integrating technology. Further research is required to establish the role that team teaching plays when teachers are attempting to integrate technology.**

This research featured team-teaching pairs who were also part of groups that assisted each other in planning and teaching of PBL. This structure, organised by the deputy principal, was intended to enable teachers to share responsibilities and support each other both in preparation for teaching and in the classroom. Unsurprisingly, there was evidence of both sharing and support occurring in respect of trying to integrate technology. However, in some cases, resulting in individual teachers being able to take on roles prior to teaching and in the classroom, which meant they were not exposed to professional learning nor did they attempt to integrate technology in the classroom.

The team-teaching approach meant, for some of the teaching teams, that only one teacher

from a teaching pair was involved in the pedagogical discussion session and that same teacher engaged with the SDLs as they provided in-class assistance. As described above, the team-teaching structure grouped each teaching team with another team. In the case of Marg and Faith, these groupings enabled both teachers in a team-teaching pair to not attend the pedagogical discussion session and, to a large extent, hand over responsibility for technology integration in their classroom to other teachers and the SDLs.

Thus, team teaching, in this context, provided opportunities for teachers to not integrate technology in their practice, despite the need for students in their classroom to be taught how to use certain technologies. The team-teaching structures gave teachers conditions where they could have these responsibilities taken up by others. This has implications when involving SDLs in trying to influence teachers' knowledge and practice, but also in a wider sense when team teaching is used and attempts are made to try to enhance teachers' knowledge and practice in technology integration. It is therefore recommended that further research be carried out that looks at team teaching, professional learning and attempts to improve teachers TPACK and their practice when trying to integrate technology.

6. **Knowledge of context (XK) is a significant aspect of TPACK and was influential in this research. Further research is required that recognises this addition to the TPACK diagram and applies it to establish how such a focus enables teachers to be considered as agents of sustainable change.**

The setting for this case study was a school that had student voice as part of its improvement plans and had a culture where students were involved with teachers in roles intended to improve teaching and learning. Even though the involvement of SDLs in the three sessions approach held for this research, had never been attempted at the school before and the scale of SDLs was far in excess of anything they had done previously, teachers' exposure to SDLs in the school was not a new concept. SDLs had worked with teachers and in school projects in other ways prior to this research. This explanation is provided to demonstrate the

existing culture in the school and to give some scale of how established it was.

Findings in this research point to teachers being aware of the influence of contextual factors such as the student voice culture and how that affected their willingness to collaborate with the SDLs. There was evidence of both effects on teacher knowledge and practice. Hence, it can be said that seeing contextual knowledge (XK) as, "integral to the…representation of TPACK" (Mishra, 2019, p. 77) was significant for this research study.

According to Mishra (2019), the implications of adding XK to the TPACK diagram and conducting research with this in mind, "allows us to go beyond seeing teachers as designers of curriculum within their classrooms but rather as intrapreneurs—knowing how their organization functions, and how levers of power and influence can effect sustainable change" (p. 77). This suggest a different focus than the research question posed in this study and perhaps a more longitudinal study. Looking at teachers working from the basis of knowledge of, "how their organization functions" (Mishra, 2019, p. 77), and then seeing how this knowledge is interpreted and used by those teachers to, "effect sustainable change" (p. 77) in respect of technology integration is recommended for future research. However, as already discussed on p. 325, XK should be seen from both a positive and negative lens. It has the potential to constrain but also to afford sustainable change.

10.3. Concluding statements

This research study has featured case studies of teacher professional learning, considering the complex issue of teachers trying to integrate technology in their classroom practice. It has focused on how the introduction of students in SDL roles influences teachers' knowledge and practice, which addresses gaps in the research literature. It has suggested five propositions, which have five implications and recommendations for further research related to this study's findings.

It adds to the understanding of how teachers' knowledge and practice when trying to integrate technology can be influenced by students. Having SDLs with training and experience offers a different perspective on teacher professional learning of digital technologies. Although featuring a relatively small number of teachers in one school as case studies and featuring observations that may have been influenced by my position as a leader in the school, this research provides a number of contextual factors. These factors contribute to propositions and implications for research in teacher professional learning focusing on technology integration as well as research in TPACK and CoP in education.

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Appendix

Appendix A

Summary of research on sharing TPACK with secondary or high school students:

Author	Title	Setting	Study aims
Webb (2014)	Pedagogy with information and communications technologies in transition	Secondary or high school	Developing and understanding shared expertise of students and teachers as knowledge is developed through increased access to technology which prompts shifts in pedagogy
Kihoza et al. (2016)	Classroom ICT integration in Tanzania: Opportunities and challenges from the perspectives of TPACK and SAMR models	University or teacher training college	Assessing opportunities for and challenges with technology integration through case study research involving tutors and pre-service teachers
Di Blas et al. (2018)	Italian teachers and technology-knowledge training	Remotely through correspondence via a university to secondary school teachers	Understanding how Italian teachers develop their TK in a distributed TPACK model
Wong et al. (2015)	Employing the TPACK framework for researcher-teacher co-design of a mobile-assisted seamless language learning environment	University and primary schools	Design of a technology-enhanced learning environment for primary school students in Chinese language learning and the use of distributed TPACK between teachers and researchers to develop the environment

Appendix B

Interview questions for teachers:

Themes	Questions	Probes
Technology integration	Other than working with students, did you find any barriers to using technology as intended in the training/teaching provided? If so, what were they?	Did the technology work as intended? Was there sufficient time given over to the program?
	Do you feel that your knowledge and practice have advanced in respect of 3D digital design as a result of being trained by the students?	Do you think it has also more broadly affected your knowledge/skills/confidence in using technology in your teaching practice? Do you think the students' involvement in the training/teaching program enhanced its quality?
Identity	Do you see the students you have been trained/taught by in the same way as you would being trained/taught by anybody else?	Were there any occasions where you doubted their credibility in the role/their ability to be able to train you how to use the software?
	Do you think that being trained/taught by the students involved has changed how you view/interact with them outside of the program? If so, how?	In what ways has it changed anything when you teach them in other lessons? In what ways has it changed anything when you see them around school?
	In what ways did being involved with students in the program change your views as to the validity of being trained/taught by students?	
Boundaries & Brokers	I have observed you working with the student Digital Leaders/using materials they created. Have they influenced you in anyway and if so, how?	Have they introduced you to terminology/language that you were not previously aware of and now use in your practice? Have they shown you ways of approaching 3D Design you were not previously aware of and now use in your practice?

Interview questions for senior leaders:

Themes	Questions	Probes
Technology integration	Other than working with students, did you witness/perceive/have reported to you, any barriers to using technology as intended in the training/teaching provided? If so, what were they?	Related to technology working as intended? Related to time given over to the program? Any other factors?
	Do you feel that for the teachers' involved, their knowledge and practice advanced in respect of 3D digital design as a result of being trained by the students?	Do you think it has also more broadly affected teachers' knowledge/skills/confidence in using technology in their teaching practice? Do you think the students' involvement in the training/teaching program enhanced its quality?
Identity	Have you witnessed/perceived/had reported to you, anything where teachers involved doubted the credibility/ability to be able to train of the students involved?	Was there anything you said/did that changed those views? If so, what?
	Have you witnessed/perceived/had reported to you anything that makes you think that teacher involvement in the program has changed relationships with the students they work with? If so, how?	Has it extended out to when they teach them in other lessons? When you see them around school?
Boundaries & Brokers	Have you witnessed/perceived/had reported to you, anything where the student Digital Leaders/use of materials they created has influenced the teachers involved in anyway and if so, how?	Have you heard any terminology/language that you think came from the student Digital Leaders? Do teachers' approaches to using 3D Design seem to be coming from the students?

Appendix C

Survey questions provided to the teachers:

Themes	Questions	Response possibilities
Technology integration	What are your views on use of digital technology in your teaching practice?	My view is that digital technology should be used as little as possible in my practice. My views are that digital technology has only a small place in my practice. I believe that I should use digital technology sometimes in my practice. I believe that I should use digital technology a lot in my practice. I believe that I should maximise any opportunities to use digital technology in my practice.
	I am confident generally in using digital technology as part of my teaching practice	Answer 1 to 5: 1 = Strongly disagree 5 = Strongly agree
	I have a high skill level generally in using digital technology as part of my teaching practice	Answer 1 to 5: 1 = Strongly disagree 5 = Strongly agree
	I am confident in using 3D Design software as part of my teaching practice	Answer 1 to 5: 1 = Strongly disagree 5 = Strongly agree
	I have a high skill level in using 3D Design software as part of my teaching practice	Answer 1 to 5: 1 = Strongly disagree 5 = Strongly agree
	I am confident in using wireframing software as part of my teaching practice	Answer 1 to 5: 1 = Strongly disagree 5 = Strongly agree
	I have a high skill level in using wireframing software as part of my teaching practice	Answer 1 to 5: 1 = Strongly disagree 5 = Strongly agree
Digital Leaders Training	What are your general views on digital technology training based on past experiences?	I rarely enjoy it. I do not often enjoy it. I sometimes enjoy it. I often enjoy it. I have always enjoyed it.
	Have you ever been trained in use of digital technology by students?	Yes. No.
	Have you ever had in-class assistance from students with technology (Student Digital Leaders assisting teachers with delivery to students, focusing on technology during classroom activities)?	Yes. No.
	I am looking forward to being trained by students	Answer 1 to 5: 1 = Strongly disagree 5 = Strongly agree
	I am looking forward to having in-class assistance from students with technology	Answer 1 to 5: 1 = Strongly disagree 5 = Strongly agree

Teaching Program	To what extent do you feel that you are working with the rest of the teachers on the Year 8 PBL course towards a shared goal? Leaders/use of materials they created has influenced the teachers involved in anyway and if so, how?	Not at all. Not much. Somewhat. Considerably. Very much.
	Please explain your response to the last question.	
	To what extent do you feel that you are working with the rest of the teachers across the school towards a shared goal?	Not at all. Not much. Somewhat. Considerably. Very much.
	Please explain your answer to the last question.	