VARIATION IN AUSTRALIAN TEACHERS' EXPERIENCE OF PROFESSIONAL LEARNING THROUGH OPEN EDUCATION

A Thesis submitted by

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ABSTRACT

The Australian Government aims to increase student engagement and achievement in Science, Technology, Engineering and Mathematics (STEM) education. One strategy to achieve this is through professional learning, which aims to improve the capacity of teachers and the quality of their teaching in this area. For many teachers, however, professional learning lacks effectiveness and meaning, and is perceived as being fragmented and irrelevant to the realities of classroom practice. Therefore, knowing which approaches to professional learning teachers find meaningful will not only benefit teachers, but also those who design and deliver professional learning experiences for teachers.

Open Education is a contemporary approach to professional learning. In the context of this study, Open Education is associated not only with resources, but with the culture and practices of teachers enabled through interactive Web technologies. Research into the different meanings teachers attribute to their experiences of this approach to professional learning is limited. Therefore, this study explores and describes the experience of professional learning through Open Education (PLOE) from the perspective of teachers of STEM subject areas experiencing this phenomenon. The intention of this study is to inform the design and delivery of meaningful professional learning to other teachers seeking to learn about STEM education through the experience of Open Education.

Phenomenography, an interpretive research methodology, was used to explore the experience of PLOE from the perspective of teachers involved in STEM education. This required three types of data. Firstly, demographic information was collected via an online survey to ascertain variation in the sample of teachers who responded. Secondly, preliminary information about the teachers' understanding of PLOE was collected via the same online survey to derive a common language through which this abstract phenomenon could be explored. Finally, empirical data were collected through semi-structured interviews with 20 Australian Primary and Secondary teachers of STEM subject areas who were engaged in PLOE. Following the removal of transcripts used for the piloting and refinement of interview questions, data analysis and subsequent findings were based on the interviews of 16 teachers.

Interview transcripts were analysed for the different ways PLOE was experienced in terms of meaning and the structural relationships between these meanings. The findings reveal that PLOE was experienced in six qualitatively different ways. Presented as categories

of description, of which the titles reflect their meaning, these are: Reclaiming autonomy; Filling knowledge gaps; Being part of something much bigger; Building on the ideas of others; Learning while teaching; and Personal and professional change. These categories were found to be structurally related through five critical aspects of which teachers were aware: the learning experience; learning practices; openness; learning problems and barriers; and validation of learning. These findings constitute the outcome space of the phenomenographic study.

These findings contribute new empirical evidence about the meaning teachers involved in STEM education attribute to their professional learning experiences. It makes an important contribution to knowledge in the areas of Open Education and professional learning, where this approach to professional learning can be understood from the perspective of the learners themselves. The outcome space has a practical application, where variation of experience can be used to design and deliver meaningful professional learning for teachers learning about STEM education through Open Education.

CERTIFICATION OF THESIS

This Thesis is entirely the work of Penelope Anne Bentley except where otherwise acknowledged. The work is original and has not previously been submitted for any other award, except where acknowledged.

Principal Supervisor: Dr Catherine Arden

Associate Supervisor: Dr Kate Davis

Student and supervisors signatures of endorsement are held at the University.

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This work is dedicated to memory of Dr Jennifer (Jenny) Donovan.
In her words, “Life is a song, and I love singing it!”

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LIST OF ABBREVIATIONS

ACARA	Australian Curriculum and Assessment Reporting Authority
ACSA	Australian Citizen Science Association
AITSL	Australian Institute for Teaching and School Leadership
CASTL	Carnegie Academy for the Scholarship of Teaching and Learning
CC	Creative Commons
COVID-19	Coronavirus Disease 2019
CSER	Computer Science Education Research Group
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EOI	Expression of Interest
GERM	Global Education Reform Movement
ICT	Information and Communication Technology
MOOC	Massive Open Online Course
NAPLAN	National Assessment Program - Literacy and Numeracy
OA	Open Access
OE	Open Education
OER	Open Educational Resources
OEP	Open Educational Practices
PCK	Pedagogical Content Knowledge
PLE	Personal Learning Environment
PLN	Personal (or Professional) Learning Network
PISA	Program for International Student Assessment
PLOE	Professional Learning through Open Education
STEM	Science, Technology, Engineering, and Mathematics
STEAM	Science, Technology, Engineering, the Arts, and Mathematics
TPACK	Technological Pedagogical and Content Knowledge
TIMSS	Trends in International Mathematics and Science Study
UNESCO	United Nations Educational Scientific and Cultural Organisation
USQ	University of Southern Queensland
VCAA	Victorian Curriculum and Assessment Authority

CHAPTER 1. INTRODUCTION

In this chapter I introduce my study as an inquiry into the different ways Open Education is experienced by Australian teachers involved in STEM education as an alternative and contemporary approach to professional learning. In the context of this study, Open Education is associated not only with resources, but with the culture and practices of teachers enabled through interactive Web technologies (Brown & Adler, 2008; Peters & Britez, 2008). The purpose of the study is to reveal what the experiences of this self-directed and informal approach to professional learning mean to Australian Primary and Secondary teachers of Science, Technology, Engineering, and Mathematics (STEM) subject areas. My argument is that people involved in the teaching profession, and in teachers' professional learning, need to understand more about teachers professional learning from the perspective of teachers themselves. My reasons for putting forward this argument are explained in more detail in this chapter.

I begin this chapter by positioning myself in the research through a description of my background and motivation for the study. This serves to identify the problem of interest and why I want to elucidate the problem. Then I refer to the context of Australian teachers of STEM subjects work, and professional learning, from which this study emerged. Next, I refer to the literature on K-12 teachers' professional learning, and professional learning in the area of STEM education in particular, including the literature related to professional learning through Open Education. In doing so, I identify the different areas of scholarship that I draw on in the literature review. Following that, I explain the choice of methodology used, arguing that phenomenography is the most suitable approach to answer the main the research question: What are the qualitatively different ways that professional learning through Open Education is experienced by Australian teachers involved in STEM education? In the next section, I provide an outline of this thesis to guide the reader through each chapter. I then define the key terms as they are applied in this thesis before concluding with a summary of the key points of this chapter.

1.1. The Biographically Situated Researcher

My interest in this research topic emerged from my formal education, an early career in scientific research and the experience of teaching mathematics, science and chemistry for over 20 years in Australian secondary schools. As a young adult I believed that information about the world we live in is obtained via our senses, can be measured and converted into useful knowledge. A short career in medical research followed by a new beginning as a secondary science teacher sustained this world view. My philosophical stance had emerged. I believed my observable world was real (ontology) and that knowledge was gained through observable experience, perceived by our senses (epistemology). In the early 1980s when my teaching career began, science education was much the same as when I went to school. Conceptual knowledge was emphasised in separate topics, standard textbook questions were answered using abstract concepts, and scientific context was taught as an add-on if time permitted. I had faith in science and science education, and working in a Catholic school was not going to change my view of the world and the teaching of it. Life, however, is not always predictable.

I faced deeply personal, emotional 'science based' issues several years into my teaching career; a medical emergency, conception via in vitro fertilisation and the brain death of a sister. These were personal experiences that raised complex questions intimately connected to human emotion, medical science, and science education. Do I have surgery? Should I agree to the disposal of unused embryos? Was it right to turn off the machine that kept my sister alive? Should I share these experiences with my students? I became increasingly concerned that the view of science I presented to students only touched on ethical issues. Life was not like the determined, measured, controlled, and summarised version of textbook science. It is random, unpredictable, and messy. No wonder students were becoming disengaged; the version of science I was expected to teach lacked humanity, context, relevance, and social connection.

Working as a science teacher in a Catholic school for many years, as an atheist, was a challenge. For example, evolution and reproduction, two controversial topics for science teachers, needed a sensitive approach when answering the inevitable student questions. Careful manoeuvring through the different world views of teachers and parents was needed in the staffroom, during curriculum meetings and parent teacher interviews. I struggled to

reconcile these differences and could see my students needed knowledge with a human dimension to reflect the true nature of science and the world they were living in. At the time I read the educational research as a means of learning more about teaching and student learning, but found it was conducted in a similar way to the scientific method I was familiar with. Empirical research provided a theoretical understanding of teaching and learning applicable to professional practice. It was grounded in the positivist paradigm and strove to limit the multitude of variables and individual differences students exhibited in the frontline of classroom teaching. But to me there was no average child, best fit pedagogy, or ideal environment. Every minute of every day was different, unique, and challenging. Individual differences, social interactions, emotional responses, and environmental conditions all had an impact on how each student experienced every day. I never did find that one size fits all generalised theory of teaching and learning to inform my teaching through those challenging times.

Reform to improve student learning was often implemented in response to new models of teaching and learning, changing assessment requirements, political influences, and school policy. What I needed to develop my practice, however, was to share experiences with other teachers to learn their tacit knowledge of 'what worked'. I was becoming aware of the uniqueness of science teachers, their varied perspectives and pedagogies. For example, next to my classroom worked another science teacher who taught exactly the same curriculum as myself. We had many similarities but when we talked, that was a different matter. My glass was often half-empty; hers was always half-full (Willing, 2001). Her pedagogical approach was more student-centered, enabling students to co-operate and learn together. Her students often worked in groups on projects they had more control over. My colleague was adopting a constructivist approach to teaching (Taylor, 2013). 'Getting into her head' for advice was vastly more meaningful to me for developing my practice than getting periodicals out of the library for weekend reading.

What I came to realise was that "The same phenomenon or event can be described in different ways, giving rise to different ways of perceiving and understanding it, yet neither way of describing it is necessarily wrong" (Willing, 2001, p. 7). I was interpreting and making meaning out of the experiences of other teachers. I was learning by constructing knowledge from the experiences they shared with me. The knowledge from within the minds

of others had a real impact on my teaching practice and shifted my thinking about the nature of knowledge. It raised questions about research into this kind of 'knowing' and I discovered that "Social science research is concerned with people and their life contexts, and with philosophical questions relating to the nature of knowledge and truth, values, and being which underpin human judgements and activities" (Somekh & Lewin, 2011, p. 2). I never questioned that my observable world was real but understood there exists multiple meanings of the same experience. I could see that not only is knowledge gained from our perceptions of the world, but it can also be socially constructed. My philosophy about reality and the nature of knowledge shifted from the positivist paradigm towards the interpretive paradigm. I believe my changed philosophical perspective influenced how I viewed the world and the many challenges I faced during my teaching career.

Throughout my 20 years of classroom teaching I experienced many curriculum, pedagogical, administrative, technical, political and professional learning changes. I also faced significant professional challenges with the introduction of digital technologies for learning and teaching, and the changing nature of science and mathematics education. Over this time the tools of my trade changed from chalk and blackboard, to markers and whiteboard, to mouse, computer and the Internet. The uniqueness of every student and teacher I worked with, and the complexity of our daily experiences, remained the same. Unfortunately, the professional learning I experienced was intermittent, generalised, and rarely meaningful. However, within the staffroom, a constant, yet informal, exchange of resources, ideas, and encouragement flowed; and teachers were open to sharing and improving their practice, together. I believe this culture of openness enabled meaningful and continuous professional learning, facilitating my growth from novice to experienced teacher.

In 2012 I resigned from my teaching position yet continued to learn about, and remain empathetic towards, science and mathematics teachers working in a climate of reform, standardisation, and accountability. I experienced the Internet as it developed into an interactive social platform, often referred to as Web 2.0 and/or the participatory Web, through which teachers shared resources and ideas, not only within their staff rooms but also between schools around Australia, and the globe. Against this backdrop, the roll-out of the Australian Curriculum stimulated robust conversation amongst teachers on the Web regarding the integration of science and mathematics under the umbrella term of Science, Technology,

Engineering and Mathematics (STEM) education. It appeared to me that teachers were experiencing meaningful professional learning through digital technologies, on the Web; thus, the notion of using digital technologies to replicate the informal culture of learning I experienced in the staffroom emerged as an interesting phenomenon to explore and understand.

I found myself as a researcher once again, this time in the field of social sciences. I wanted to explore and understand, from the perspective of Australian teachers involved in STEM education, this informal professional learning they were experiencing on the Web. Inspired by an appreciation for others who broadened my understanding of teaching by sharing their different experiences and perspectives with me, exploring variation of experience also emerged as an aspect of this study. Therefore, I chose to explore the different experiences of Australian teachers of STEM subject areas who used the Web for professional learning. This became the focus of my PhD inquiry. However, as a researcher in the social sciences I had to think about 'what do I know and how do I know it'? My previous world view in the positivist paradigm no longer sat comfortably with my research philosophy. I could not isolate and 'measure' the thoughts, feelings and emotions teachers attributed to their experiences. Instead, I needed to interpret descriptions of their professional learning experiences in order to 'know it'. Thus, I undertook an interpretive inquiry (Creswell, 2007). It is from this paradigm the methodology of choice for my research inquiry, phenomenography, emerged. Phenomenography resonates with me as a way of revealing the different ways Australian teachers involved in STEM education experience professional learning on the Web, a phenomenon I refer to as Professional Learning through Open Education (PLOE).

Motivation for this investigation thus arose from my experience of professional learning while employed as an Australian secondary teacher of STEM subject areas; an appreciation for the informal ways teachers learn; an interest in digital technologies for learning and teaching; and an awareness of the changing nature of science and mathematics education. In addition to my background and motivation, the context within which Australian teachers of STEM subject areas currently work contributes to my reasons for conducting this study. Central to my reason for undertaking educational research is the desire to make the voices of teachers heard as they work tirelessly to evolve with their changing practice. Their

voices are often difficult to hear over the noise of politicians, administrators, and public media. From previous, anecdotal evidence and my own experience, I know science teaching is complex and that teachers' perceptions of daily experiences are rich and varied. Therefore, I can relate to and have empathy with the experiences of teachers in this study.

I am aware that my previous experience as teacher of STEM subject areas, and being a user of the Web for professional learning, both have the potential to influence my findings. As the researcher, these influences exist at every stage of the research design. I am not independent of the research process. I designed the study, interviewed the teachers, interpreted the data, and in this thesis discuss and present the findings. However, this inquiry is not about what I bring to it as a researcher. One way of minimising my influence is through documenting and maintaining reflexivity throughout the research process. Reflexivity refers to me, the researcher, identifying, attending to and minimising the effects of my preconceptions (Sin, 2010). Issues of researcher reflexivity are discussed in Chapters 3 and 4. My challenge as a researcher is to listen to and retell participants' experiences in a way that may have meaning for others. I will not find a general law to inspire science teachers and their students, but may uncover insights to inform their daily practice. Most importantly, driving this research is the empathy I share with teachers of STEM subject areas as they adapt to educational change and reform.

1.2. Purpose and Aims of the Study

The research problem from which this study emerged is teachers' perceptions – as experienced by myself, my colleagues and supported in the literature – that professional learning can lack effectiveness, meaning, and relevance to classroom practice (Cole, 2012; Lieberman & Pointer Mace, 2010; Opfer & Pedder, 2011; Webster-Wright, 2009). Teachers' perceptions of the ineffectiveness of their professional learning experiences may be attributed to any number of factors, such as time limitations, presenter skills, lack of specificity or relevance, and/or not being personalised to individual needs (Cole, 2012). In fact, metaphors implying ineffectiveness, such as 'spray-on' (Mockler, 2005, p. 4), or 'drive by' (Senge et al., 2000, p. 385) are used by teachers and researchers to describe the nature of professional learning. Therefore, I chose to explore the different ways an alternative and contemporary approach to professional learning, Open Education, is experienced by Australian teachers involved in STEM education, from their perspectives.

The aim of the study is to find and explore the different meanings these teachers attribute to their experiences of professional learning through Open Education (PLOE). In doing so, my objectives are to:

- Make a knowledge claim regarding variation in the ways professional learning through Open Education is experienced from the perspective of Australian teachers involved in STEM education.
- Present a model/framework representing this knowledge claim.
- Inform the development and delivery of meaningful professional learning to teachers who work in a similar context to those who participated in this research.
- Make theoretical contributions to the fields of professional learning, Open Education and to a lesser extent, adult learning.

To generate findings applicable to the purpose of this study, the main research question is: What are the qualitatively different ways that professional learning through Open Education is experienced by Australian teachers involved in STEM education? This question was approached through three sub-questions:

RQ1: What are the different meanings Australian teachers involved in STEM education attribute to the experience of PLOE?

RQ2: What aspects of PLOE are critical to the different ways this phenomenon is experienced by Australian teachers involved in STEM education?

RQ3: How can the new knowledge gained from RQ1 and RQ2 be used to design professional learning experiences for Australian teachers involved in STEM education?

1.3. Why is this of Concern?

Teachers are the focus of efforts to increase student engagement and performance in STEM subject areas, since it is widely recognised that all teachers have a significant and influential role in the classroom, where their efforts are linked to student achievement (Education Council, 2018a; Muijs et al., 2014). It is assumed, therefore, that helping teachers to increase their subject knowledge and classroom practices through professional learning should lead to improved student learning (Education Council, 2015, 2018a). However, evidence for improved student outcomes in any subject area, via teacher professional

learning, is inconsistent (Darling-Hammond et al., 2017). It seems that professional learning does not always facilitate change in teacher practice nor transfer into improved student outcomes (Cole, 2012; Desimone & Garet, 2015). Whether new approaches to professional learning for teachers involved in STEM education have an impact on teacher practice and/or student learning is yet to be established. There is a dearth of literature on the effectiveness of professional learning for STEM education, particularly from the perspective of teachers. The question needs to be asked: what is the nature of effective professional learning for Australian K-12 teachers involved in STEM education?

In the literature on K-12 teachers' professional learning there is no precise definition of effective professional learning. Ambiguity exists around the use of this term. 'Effective professional learning' could refer to improvement in student outcomes (Darling-Hammond et al., 2017), changes in the beliefs and attitudes of teachers (Tondeur et al., 2016), and/or changes in the practices of teachers (Whitworth & Chiu, 2015). It could also refer to professional learning experiences having certain characteristics, contextualised to specific conditions, such as being ongoing, interactive, content-focused, collaborative, and coherent (Desimone, 2009, 2011). Similarly, it could refer to generalised characteristics such as professional learning being relevant, collaborative, and future focused (Australian Institute for Teaching and School Leadership [AITSL], 2012b). Regardless of how effectiveness is defined, professional learning is recognised as a complex process (Avalos, 2011; Boylan et al., 2018; Opfer & Pedder, 2011). In this study there is no intent to single out any one definition of the effectiveness of professional learning in terms of its impact on students and/or teachers, or its features and characteristics, but merely to highlight the different ways effectiveness is perceived by teachers and researchers.

Since the perspectives of teachers influence what they do in the classroom, and teachers influence student learning, it is important to explore and understand the views teachers have about their experiences of professional learning. One way to do this is to ask teachers about their professional learning experiences. The question then becomes: what to ask them? Since effectiveness is not clearly defined, a change of focus to the meaning teachers ascribe to their professional learning experiences is appropriate. This is especially so as teachers are adult learners, and the literature in this field speaks more of meaning than the effectiveness of experience. For instance, experience is a central concept in transformative

learning theory, a theory of adult learning (Mezirow, 1981; Taylor & Cranton, 2013). Taylor and Cranton (2013), scholars in the field of transformative learning, claim that experience is also an under explored concept. To stimulate development of this theory they encouraged researchers to explore questions related to the nature of experience, the meaning of experience, how to describe experience, and to distinguish between different kinds of experiences (Taylor & Cranton, 2013).

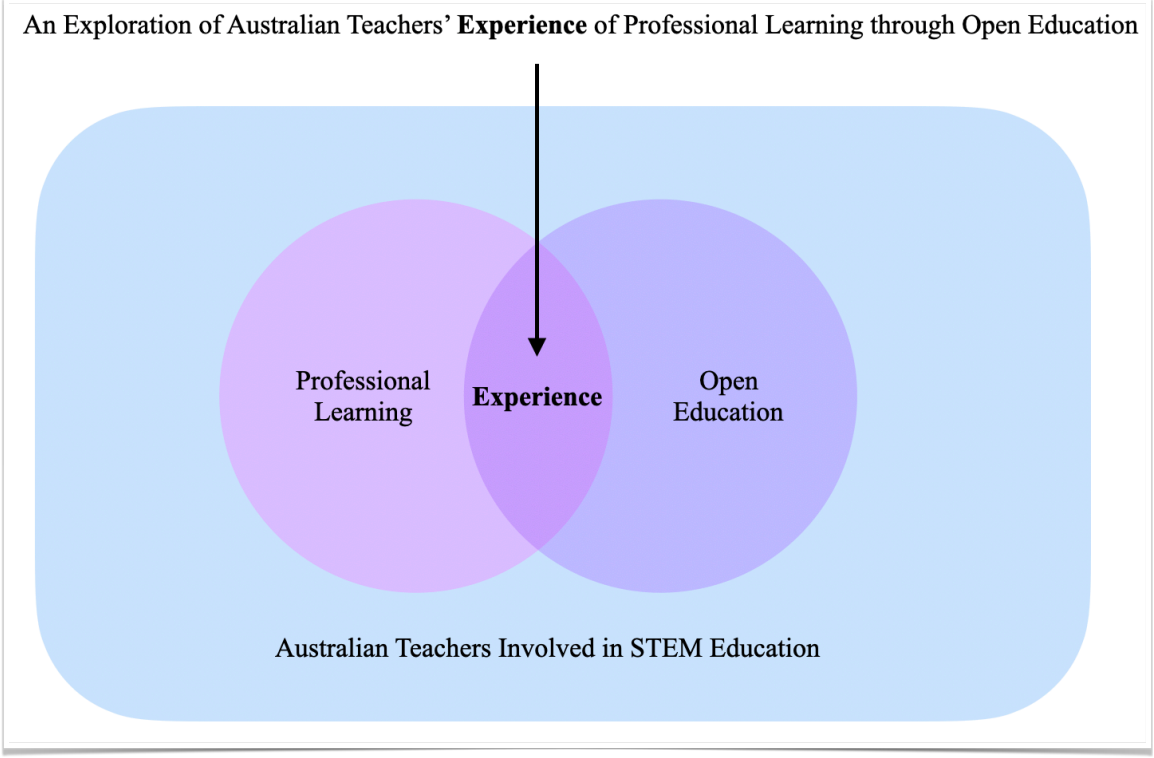
Teachers are adult learners, however, adult learning is not the focus of this study. Even so, this is a recognised gap in the literature related to this field. Mezirow (1990) posits that the meaning people interpret from their experiences guides their decision making and/or actions, and in this sense "making 'meaning' becomes 'learning'" (Mezirow, 1990, p. 1). Therefore, exploring teachers' experience of professional learning, and the meaning they interpret from their experiences, is important when it comes to the STEM pedagogical decisions and actions they apply in the classroom. Since there is a recognised link between the perspectives and beliefs of teachers and their classroom practice (Pajares, 1992), it follows that if teachers believe their professional learning is ineffective, regardless of the reason, their beliefs may have a negative impact on their practice (Biesta et al., 2015). Conversely, one could reasonably conclude that, if teachers interpret their professional learning experiences to be meaningful, this may have a positive influence on their decision-making and actions in the classroom.

To summarise, Australian STEM education is a developing area of research (Fitzallen & Cooper, 2019). Within the emerging literature I have identified little about K-12 teachers' professional learning in the area of STEM education, and in particular, their experiences of professional learning in this area. Similarly, there is little known about K-12 teachers' experiences of Open Education, even though research into the concept of Open Education is broadening (Kimmons, 2014). Despite professional learning being widely researched, studies focusing on the perspective of teachers are limited, particularly the perspective of teachers as adult learners (Webster-Wright, 2009). These issues will be elaborated in my literature review in Chapter 2, in which I draw on three main areas of scholarship to inform my study: the context of Australian K-12 teachers involved in STEM education; professional learning; and Open Education. These areas of scholarship are illustrated in Figure 1.1 below in which the

arrow indicates where my study is situated at the confluence of these three areas: that is, how teachers experience professional learning through Open Education.

Figure 1.1

Situating this Study in the Literature



What follows in the sections below is a clarification of the specific focus of the study with reference to the participant teachers and the concept of Open Education.

1.4. Who are Teachers of STEM Subject Areas?

My interest lies in the different ways Open Education is experienced by Australian K-12 teachers who engage in professional learning about STEM education. The focus of this study is therefore on experience, conceptualised as the relationship between teachers and their professional learning through Open Education. Teachers participating in this study are referred to as Australian K-12 teachers of STEM subject areas for several reasons. STEM is not a specific learning area in the Australian Curriculum, however, it is addressed through the learning areas of Science, Design and Technologies, Digital Technologies and Mathematics (Australian Curriculum and Assessment Reporting Authority [ACARA] n.d.-d). According to Tytler et al. (2019) "STEM is predominantly the province of Mathematics and Science, and

Technology subjects" (p. 52). The Engineering component of STEM is addressed throughout the Design and Technologies learning area, and another component, the Arts, has been known to be included in Science, Technologies, Engineering, the Arts and Mathematics (STEAM) education programs (English, 2017; Taylor & Taylor, 2019). For example, the role of aesthetics in the design and construction of famous bridges is a way to include the Arts (English, 2017). Since STEM (or STEAM) does not refer to a specific subject, teachers participating in this study are referred to as Australian teachers of STEM subject areas, and teachers involved in STEM education, instead of STEM teachers.

Participants are also referred to as K-12 teachers because they were selected from both the primary and secondary sectors of the Australian education system. Primary school teachers are generalist teachers who teach across all subjects and are responsible for teaching programs related to STEM education in their schools (Xu et al., 2019). On the other hand, Secondary school teachers are specialists in their specific STEM learning areas. At the senior levels of the curriculum, these learning areas are further subdivided into a range of STEM related subject areas (Australian Curriculum and Assessment Reporting Authority [ACARA] n.d.-c). It is worth noting, however, that it is common in Australia for Secondary teachers to teach outside their specialist areas, known as "out of field teaching" (Timms et al., 2018, p. 17). Therefore, for the purposes of this study, STEM refers more to content and process of STEM education rather than being a label that describes the teachers themselves.

1.5. What is Open Education?

Throughout this thesis I refer to professional learning through Open Education as a phenomenon (Marton & Booth, 1997), and use the acronym PLOE. There is variation in the way Open Education is conceptualised in the literature. It may refer to the historical origins of this concept in 20th century K-12 education (Conrad & Prinsloo, 2020; Peters & Britez, 2008, p. 6; Peter & Deimann, 2013). For example, "The Open Classroom" and "Open Schooling" are two moments in history that emphasised freedom, democracy, autonomy, self-expression, creativity, and concepts such as "self-directed" learning, "informal education", and "learning by doing" (Peters & Britez, 2008, p. 8). This culture of openness that appeared throughout the history of education is now enabled through "technologies of openness" provided by the Web (Peters, 2014, p. 1). Often referred to as Web 2.0, and/or "The Participatory Web" (Floridi, 2009, p. 35), these technologies are interactive, and encourage

participative and collaborative experiences. Thus, Open Education can refer to many things, such as the practices of teachers, the resources they use for teaching and learning, educational policies, values, and/or relationships between people (Cronin & MacLaren, 2018). In fact, Cronin and MacLaren (2018) ask the question "is open education a slogan or a philosophy, a metaphor, model, or movement?" (p. 127).

When reflecting on this question to describe Open Education as it is used in this study, I was also guided by the Cape Town Open Education Declaration which states that:

> …open education is not limited to just open educational resources. It also draws upon open technologies that facilitate collaborative, flexible learning and the open sharing of teaching practices that empower educators to benefit from the best ideas of their colleagues. (Cape Town Open Education Declaration, 2007, para. 4)

Thus, I see the experience of Open Education as being enabled through interactive Web technologies, and includes resources, practices and a culture of sharing and participation. I also see Open Education as enabling seamless learning experiences that are informal, self-directed and occur across different locations, times, and contexts (Looi et al., 2019). In the next section I will situate this study in the context of contemporary Australian education policy and STEM education.

1.6. Context of Australian Teachers of STEM Subjects' Work

Currently, the educational landscape within which Australian teachers work is one of accountability, standardisation and reform (Dinham, 2013; Mockler, 2013a). These issues permeate the workplaces of teachers, building a "culture of compliance" instead of a "culture of professional learning" (Lieberman & Pointer Mace, 2008, p. 227). For instance, teachers are obliged to meet their annual teacher registration requirements (Victorian Institute of Teaching [VIT], n.d.), align their practice with professional standards that do not prioritise STEM subject areas (Australian Institute for Teaching and School Leadership [AITSL], n.d; Fraser et al., 2019), and prepare students for standardised assessment of their learning (National Assessment Program, n.d.). Additionally, since comparative international testing shows the performance of Australian students continues to decline in the areas of science and mathematics (Thomson et al., 2019), there is a focus on STEM education in the Australian curriculum (Australian Curriculum and Assessment Reporting Authority [ACARA] n.d.-d). This STEM focus means that teachers are expected to implement changes in the Australian

Curriculum within their respective State curriculum frameworks, such as those provided by the Victorian Curriculum and Assessment Authority (VCAA, n.d.).

In line with curriculum change, another aspect of the Australian Government's reform effort is to increase student interest, participation and achievement in STEM subject areas through the professional learning of teachers (Education Council, 2015, 2018a; Freeman et al., 2019; Tytler et al., 2019). Currently, there is no requirement for Australian teachers to undertake a specific number of hours of professional learning related to the content and pedagogy of the subjects they teach (Education Council, 2018a). Nevertheless, the need for effective professional learning for teachers involved in STEM education is evident.

1.7. What is Professional Learning?

What is professional learning and what kinds of professional learning are available for teachers to experience? The Australian Institute for Teaching and School Leadership [AITSL] defines professional learning as:

> …the formal or informal learning experiences undertaken by teachers and school leaders that improve their individual professional practice, and a school's collective effectiveness, as measured by improved student learning, engagement with learning and wellbeing. At its most effective, professional learning develops individual and collective capacity across the teaching profession to address current and future challenges. (AITSL, 2012b, p. 2)

Thus, professional learning is seen as formal, informal, individual, collective, current, and future focussed. As Lloyd and Davis (2018) identified, professional learning requirements for teacher registration vary across Australian States and Territories. Regardless of this variation, for many teachers across Australia, the main approach to professional learning is through "formally provided courses, peer observation, seminars and master programs" (Lantz-Andersson et al., 2018, p. 303).

Increasingly, however, teachers are gaining professional learning through other means such as coaching (Kraft et al., 2018), professional learning communities (Owen, 2016), and programs targeted specifically at K-12 teachers involved in STEM education (Educational Council, 2018a). Additionally, many opportunities for professional learning occur on the Web and fall under the banner of Open Education (de los Acros et al., 2016), such as participating in Massive Open Online Courses (MOOCs) (Laurillard, 2016; Vivian et al., 2014), using

social media (Kelly & Antonio, 2016; Fischer et al., 2019), and creating Personal Learning Networks (Oddone et al., 2019; Prestridge et al., 2019).

Since the range and type of opportunities available for teachers to learn is broad, in this study professional learning is understood as learning that results from any experience where teachers themselves consider they have learned related to their roles as teachers (Webster-Wright, 2009). Professional learning also constitutes the process that teachers engage in when they expand, refine, and change their practice (Mockler, 2015). This study will incorporate both aspects. I wanted to explore and understand, from the perspective of Australian teachers involved in STEM education, this informal professional learning they were experiencing on the Web. I also chose to explore variation in their experiences. My previous world view in the positivist paradigm no longer sat comfortably with my research philosophy. I could not isolate and 'measure' the thoughts, feelings and emotions teachers attributed to their experiences. Instead, I needed to interpret descriptions of their professional learning experiences to 'know it', therefore undertaking an interpretive inquiry (Creswell, 2007). It is from this paradigm the methodology of choice for my research inquiry, phenomenography, emerged. For this inquiry, phenomenography was the most suitable methodology to explore variation in the experience of PLOE from the perspective of teachers. In the next section the methodology and methods of this study are outlined.

1.8. Methodology and Methods

Phenomenography is a methodology developed through empirical research in education (Limberg, 2000; Marton & Booth, 1997), and is seen as a rigorous way to conduct qualitative research (Tight, 2016). The philosophical assumptions central to understanding and conducting phenomenographic research (Bowden, 2000a) fit with my understanding of reality and the nature of knowledge. For example, I conceptualise the experience of teachers in a particular way, not as a cognitive construct in their minds, nor as part of their external reality, but as a relationship between the two. This means my ontological assumption about the nature of reality is non-dualistic, and my epistemological assumption is that new knowledge emerges from the relationship between teachers and the phenomenon of PLOE. It is this relationship, otherwise referred to as "a way of experiencing" (Marton & Pong, 2005, p. 336) that I explore as the source of new knowledge (Svensson, 1994). The

theoretical and methodological aspects of experience, as it is conceptualised in this study, are presented in Chapter 3.

To conduct this study, I collected data via an online questionnaire and semi-structured interviews with a purposive sample of Australian K-12 teachers of STEM subject areas. Teachers were selected for this study for the purpose of exploring their experiences of PLOE. In keeping with phenomenography, a sample of participants was chosen for maximum variation across certain criteria (Akerlind et al., 2005). They were qualified Australian teachers (including teacher librarians), who were registered to teach in Australian schools, worked in either the Primary or Secondary sectors, were involved in STEM education, and engaged in learning about STEM education on the Web. They also showed a range of factors such as gender, age, employment basis, teaching areas, year levels and location within Australia. The overall aim was to select participants who represented Australian teachers of STEM subject areas who were learning through Open Education on the Web, and to maximise variation of experience to be captured during the interviews (Stenfors-Hayes et al., 2013). The approaches I took to selecting participants are outlined in detail throughout Chapters 3 and 4.

Being a solo researcher, I transcribed the interviews verbatim and analysed the data for variation in meaning and awareness in teachers' experience of PLOE. The findings that emerged from phenomenographic data analysis are presented as categories of description that are related to each other and are arranged as an outcome space. The process of phenomenographic data analysis is explained in Chapter 4 and my findings are presented in Chapter 5. It is intended that these findings will be applied to the "particular practical issue that was the genesis of the research" (Green & Bowden, 2009, p. 52); that is, to the problem/ issue of professional learning that lacks meaning and relevance to teachers. Developmental phenomenography is the term used to capture such intent behind the use of phenomenographic findings (Bowden, 2000a). My findings may help teachers learn to see a phenomenon of PLOE in new, different, and meaningful ways. As Collier-Reed et al. (2009) say, "learning, in the phenomenographic tradition, points to coming to discern phenomena in new and more powerful ways" (p. 2). Additionally, my findings may be of interest to teachers who wish to direct their own professional learning, and/or to those who design for and deliver professional learning to Australian teachers in more formal educational settings.

This study is therefore significant because it explores an alternative, contemporary approach to professional learning for Australian K-12 teachers involved in STEM education. The research findings can be used in a pedagogical sense, for the professional learning of others who wish to learn about the phenomenon of PLOE. It is hoped that, if teachers find their professional learning experiences to be more meaningful, this could, in turn, positively impact on their practice in the classroom and on the learning of their students. This is useful, practical knowledge, since improving the practices of teachers through professional learning is one key area of Australia's National STEM School Education Strategy (Education Council, 2015). In the next section I will outline the chapters in this thesis.

1.9. Outline of the Thesis

Following this Introduction, the focus of Chapter 2 is to review the relevant research on teacher professional learning and Open Education, in the context of Australian teachers' involvement in STEM education. The review begins with an outline of teachers and their work in the context of contemporary Australian education policy and STEM education. What follows is a review of the research on teachers' professional learning. This includes the literature on Open Education as it relates to the professional learning of teachers in the K-12 context. Finally, the knowledge gap that will be addressed by this study is identified and elaborated.

Chapter 3 articulates the methodological framework used for this thesis, namely developmental phenomenography. It brings together into a research design my research question, philosophy, conceptual framework, and theory related to phenomenography, methods, and trustworthiness issues. My philosophical beliefs and assumptions are made explicit, as is my justification for choosing phenomenography as a methodology. Issues relevant to the relational aspects of phenomenography are also discussed.

Chapter 4 describes, in detail, the research methods adopted as a means of answering the main research question. The research strategies are outlined, such as how participants are sampled, and data are collected. Ethical considerations are discussed, so too is information regarding conducting, piloting, and implementing an online questionnaire. The focus then shifts to how the main study was conducted, particularly the piloting and implementation of the phenomenographic interview. Data analysis procedures are elaborated in this chapter,

such as which analytical framework was used, and how meaning was generated from the data. Research outcomes and the researcher's role are discussed towards the end of Chapter 4.

Chapter 5 presents the findings of data analysis described in the previous chapter. Firstly, the qualitatively different ways PLOE is experienced by a group of Australian teachers are described in detail and presented as six categories of description. These categories represent the different meanings attributed to the different experiences. The structural themes that relate the categories to each other are then described. These findings are then visualised as an outcome space.

Chapter 6 provides a discussion and summary of the research findings. It situates my findings in relation to aspects of literature review presented in Chapter 2; and discusses how they can be applied as a current approach to professional learning for teachers wanting to use the Web to learn about STEM education using the PLOE Framework. I examine the contribution this research makes to knowledge in the areas of professional learning, adult learning, Open Education. The possibilities for further research are suggested.

1.10. Definitions of Key Terms

In this section I define the key terms as they are applied in this thesis.

A way of experiencing. A way of experiencing is viewed as the "basic unit of description" in phenomenography (Marton & Pong, 2005, p. 336). In this study it is conceptualised as a relationship between a teacher and the phenomenon of professional learning through Open Education. It is also described as "a particular way of being aware of something and is seen as a relation between a person and the specific phenomenon under study" (Limberg, 2008, p. 612).

Second-order perspective. Phenomenography is concerned with describing how someone experiences a phenomenon, not describing the phenomenon itself. This is referred to as the researcher taking a second-order perspective (Trigwell, 2000).

Developmental phenomenography. An approach to phenomenography that "is designed to produce research outcomes that can subsequently be used to address a given educational or other kind of issue" (Green & Bowden, 2009, p. 52).

Experience. A relationship between individuals and phenomena in the world around them (Marton & Booth, 1997). As Marton and Pang (2008) assert, "an individual cannot experience without something being experienced" (p. 535).

Meaning. Meaning, in a phenomenographic sense, can be referred to as "the basic unit of phenomenography" (Marton, 2015, p. 105). It refers to the "different ways of seeing something, or different ways in which something appears" (Marton, 2015, p. 105).

Open Education. This is associated with the culture, practices, tools, and resources enabled through Web technologies. As stated in the Cape Town Open Education Declaration, "open education is not limited to just open educational resources. It also draws upon open technologies that facilitate collaborative, flexible learning and the open sharing of teaching practices that empower educators to benefit from the best ideas of their colleagues" (Cape Town Open Education Declaration, 2007, para. 4).

Phenomenography. A research methodology used to "investigate the range of ways in which a group of people experience a particular phenomenon" (Green & Bowden, 2009, p. 52).

Professional learning. This is understood as learning that results from any experience where teachers themselves consider they have learned something related to their roles as teachers (Webster-Wright, 2009). Professional learning also constitutes the process that teachers engage in when they expand, refine, and change their practice (Mockler, 2015). This study will incorporate both aspects.

Professional learning through open education (PLOE). A term I developed that refers to professional learning that occurs through Open Education. PLOE is an alternative, contemporary, voluntary and informal approach to professional learning that teachers experience on the Web; where Open Education is interpreted as Open Educational Resources (OER) and Open Educational Practices (OEP).

Science Technology Engineering and Mathematics (STEM). This is defined as "learning and/or work in the fields of Science, Technology, Engineering and Mathematics, including preliminary learning at school prior to entry into the specific disciplines" (Freeman et al., 2016, p. 1).

STEM education: STEM is not a specific learning area in the Australian Curriculum. This term refers to "the teaching of the STEM disciplines, as well as an integrated approach that increases interest and knowledge in STEM disciplines and improves students' problem solving and critical analysis skills" (Education Council, 2018a, p. 19). It incorporates the learning areas of Science, Design and Technologies, Digital Technologies and Mathematics

and certain aspects of the capabilities and priorities dimensions (Australian Curriculum and Assessment Reporting Authority [ACARA] n.d.-d). The general capabilities include ICT and development of higher-order abilities such as critical thinking, social capabilities, and ethical understanding (ACARA, n.d.-b). The cross-curriculum priorities include an understanding of sustainability, indigenous history and culture, and engagement in Asia (ACARA, n.d.-a).

1.11. Chapter Summary

In this chapter I introduced my inquiry into variation in the ways PLOE is experienced by Australian teachers. PLOE is an alternative, contemporary, voluntary, and informal approach to professional learning that teachers experience on the Web. I explained that the purpose of conducting this inquiry is to reveal the different meanings teachers attribute to their experiences of PLOE. I developed my argument that there is a need for meaningful professional learning for teachers involved in STEM education, who work in a climate of accountability, standardisation and reform, and who perceive their professional learning to lack meaning and relevance. Since there is a link between teachers' perceptions and actions in the classroom, and teachers influence student learning, it is useful to know about the meanings they attribute to their experiences of PLOE. I propose this new knowledge could be used to inform the development and delivery of meaningful professional learning to a similar cohort of teachers. I explained how empirical research can be conducted by using developmental phenomenography, a methodology that sits in the interpretive paradigm and enables me to use a qualitative research approach answer my research question. Motivation for conducting this study emerges from my professional experience as an Australian teacher of STEM subject areas and the extant literature that backs up my claim that this research would be useful. The key terms, as they are applied in this study, were provided to inform the reader as they are guided through this thesis by the given structure and outline of each chapter. The next chapter presents a review of the literature related to the context of contemporary Australian education policy and STEM education, teacher professional learning, and Open Education.

CHAPTER 2. LITERATURE REVIEW

In the last chapter I introduced my inquiry into variation in the ways PLOE is experienced by Australian teachers involved in STEM education. The purpose of this chapter is to review the relevant literature on teachers' professional learning and Open Education in the context of Australian teachers' work and STEM education, and to highlight the areas within which this research can contribute. As noted in Figure 1.1. in Chapter 1, there are three main areas of literature to be explored relevant to problem being investigated: literature exploring the global and national contexts of the work of Australian teachers involved in STEM education; literature on K-12 school teachers' professional learning; and literature investigating the emergence of Open Education as a vehicle for teachers' professional learning. This literature review combines studies across several broad areas of scholarship: K-12 teachers' professional learning (which includes professional learning in STEM subject areas); the workplace learning of professionals; adult education; and Open Education. These studies are not all unique to, but are comparable with, the Australian context. Within these broad areas of literature, I have also drawn upon sub-areas to highlight specific aspects relevant to this study. These sub-areas are elaborated in Section 2.3. below.

Since this research focuses on the professional learning experiences of Australian teachers involved in STEM education, the literature review begins with an overview of the literature on teachers' work – and specifically the work of K-12 teachers of STEM subjects – in the context of global change, contemporary Australian education policy and related questions of teacher quality, quality teaching and teachers' professional practice and learning. The open Web is then described in terms of its general application to education, and, more specifically, to this study. Following this, a learning metaphors framework is introduced, both as an organiser for the presentation of the review of the literature from key fields of scholarship, and to conceptualise the different ways teachers' professional learning is understood and represented in this literature. The research on teachers' professional learning through Open Education is also reviewed in the context of metaphors of learning. Finally, the knowledge gaps are highlighted to position this research and its contributions to knowledge.

2.1. The Contemporary Context of Australian Teachers' Work

In 2012, the Australian Government incorporated a long-term goal into the Australian Education Act 2013 "for Australia to be placed, by 2025, in the top five highest performing countries based on the performance of school students in reading, mathematics and science" and "for the Australian schooling system to be considered a high-quality and highly equitable schooling system by international standards" (Masters, 2016, p. 1). This ambitious goal has been pursued through the introduction of a range of government initiatives since 2007 (Dinham, 2013); including the establishment of the Australian Curriculum (Australian Curriculum and Assessment and Reporting Authority [ACARA], n.d.-a) and the Australian Charter for the Professional Development of Teachers and School Leaders (Australian Institute for Teaching and School Leadership [AITSL], 2012a); the rollout of the Australian Professional Standards for Teachers (AITSL, 2011); the introduction of the Australian Teacher Performance and Development Framework (AITSL, 2012b); and the National Assessment Program (National Assessment Program, n.d). Additionally, teachers seeking registration through their local State or Territory authorities are required to meet national standards in order to enter the teaching profession, for example, through the Victorian Institute of Teaching (Victorian Institute of Teaching [VIT], n.d.). Student participation in the Program for International Student Assessment (PISA) (Australian Council for Educational Research [ACER], n.d.-a), and the Trends in International Mathematics and Science Study (TIMSS) (ACER, n.d.-c) are aspects of Australia's education policy that also have significant implications for Australian teachers involved in STEM education.

PISA and TIMSS are comparative, international tests used to rank Australian students with others around the globe (Thomson et al., 2017a; Thomson et al., 2017b). The continued decline of Australia's international ranking of student performance in PISA mathematical and scientific literacy (Thomson et al., 2019), combined with the plateauing of student achievement in the National Assessment Program – Literacy and Numeracy (NAPLAN) tests (Australian Curriculum, Assessment and Reporting Authority, [ACARA], 2017), also have implications for how Australian teachers are judged. So, too, does the publication of NAPLAN test results on the Government's MySchool website (Thompson, 2013). To many stakeholders in education, these are not successful outcomes for students nor, more broadly, welcome trends for Australian education. In fact, sensationalist claims have been made

"about a 'crisis' in quality teaching in Australia" (Bahr & Mellor, 2016, p.15). Dinham (2013) makes the point that "rather than being seen as education's most important asset, teachers are now being blamed when students fail to learn or to reach the standards set for them individually and collectively" (p. 92). What Thrupp (1998) refers to as the "politics of blame" can have a negative impact on teachers (p. 195). For example, Thompson (2013) reports teachers experience pressure in terms of their performance and the pedagogical choices they make to improve student outcomes in NAPLAN testing. Therefore, it could be argued that Australia's educational reform agenda pushes forward to achieve the government's ambitious, long-term goal at the expense of Australian teachers who are integral to realising this goal. The implications for teachers' professional learning will be briefly highlighted in the sections below.

2.1.1. Quality Teachers or Quality Teaching?

Discourse linking teachers to the improvement of student outcomes often includes words such as 'effectiveness' and 'quality'. For example, the Australian Institute for Teaching and School Leadership (AITSL), the organisation responsible for the professional standards of Australian teachers, links standards to teacher quality, claiming:

> The Australian Professional Standards for Teachers are a public statement of what constitutes teacher quality. They define the work of teachers and make explicit elements of high-quality, effective teaching in 21st century schools that will improve educational outcomes for students. (AITSL, n.d.)

Apparently, regulation of the teaching profession through professional standards has the potential to improve the quality of teachers, their teaching, and consequently, student outcomes. However, the meaning of the term 'quality' in the context of teachers and their work, is unclear (Bahr & Mellor, 2016). In fact, the terms 'teacher quality' and 'quality teaching' are often interchanged, intertwined, and used in different ways by governments, parents, students, and the media (Belsito, 2016; Mockler & Groundwater-Smith, 2018). Yet there is a difference between these terms that is important to note in the context of teachers' professional learning (Bahr & Mellor, 2016; Darling-Hammond, 2012; Mockler, 2013a; Mockler & Groundwater-Smith, 2018).

Teacher quality is personal. It refers to the personal aspects of individual teachers: their dispositions, knowledge, and abilities (Bahr & Mellor, 2016). Consequently, the

language of teacher quality can be used to blame individual teachers, for example, when their students underachieve (Scholes et al., 2017; Mockler & Groundwater-Smith, 2018). On the other hand, teaching quality refers to what teachers do, for example, their pedagogical practices (Bahr & Mellor, 2016; Darling-Hammond, 2012; Mockler, 2013a; Mockler & Groundwater-Smith, 2018). Teaching quality also considers the political, cultural, and social context of teachers' work in schools (Bahr & Mellor, 2016), along with recognising the collegial and community aspects of their practice (Scholes et al., 2017). Therefore, teaching quality focuses more on teachers' practices than teachers as individuals (Mockler, 2018). Increasingly the quality of teachers and teaching is judged through the collection of data related to the learning of their students (Dam et al., 2020). Labelled the "datafication" of teaching, student data may be used for the purpose of teacher accountability (Buchanan & McPherson, 2019; Stevenson, 2017).

Professional learning is an important aspect of teaching quality and the improvement of teaching practice (Mockler, 2013a). There is an expectation that teachers, like other professionals, will continue to learn through their working lives (Webster-Wright, 2009). One of the purposes of the Australian education policy is to guide and support the professional learning of teachers. To actualise this purpose, teacher professional learning is now linked to externally controlled professional standards (Treagust et al., 2015). However, "teachers come away from professional development sessions wishing those designing them would make them more applicable to the ever-increasing challenges they face every day in their classrooms" (Timperley, 2012, p. 40). My study links to this concern through exploration of an alternative approach to teacher professional learning.

2.1.2. The Inevitability of Change

It is inevitable for contemporary Australian teachers to experience change. In fact, throughout history, teachers, and the schools within which they work, have adapted to global, economic, political, technological, and social change. An aspect of change Australian teachers currently experience in the context of their work is related to the paradox of 21st century education. The term GERM (Global Education Reform Movement), coined by Sahlberg (2012), has emerged to describe policies of standardisation, student testing, performance, and competition. The paradox is that GERM sits in stark contrast to the 21st century education rhetoric, for example, that all teachers should be innovative and "deliver

contemporary science using contemporary pedagogy, with a focus on creativity and inquiry-based learning" (Office of the Chief Scientist, 2014, p. 23). Aspland and Macpherson (2012) point out that discourse surrounding a regulatory professional learning culture is inconsistent with contemporary views about 21st century education.

In their work, teachers are also expected to adapt to technological change. The use of information and communication technology (ICT) for learning and teaching is one of the general capabilities embedded within the Australian Curriculum (ACARA, General capabilities, 2018). Additionally, the new Technologies curriculum (ACARA, Technologies, 2018) has been implemented across Australian schools from Foundation to Year 10. Australian teachers need to understand and incorporate digital technologies into their teaching practice, keep pace with their students, and remain current with their professional learning. Consequently, teachers need support and professional learning. Several initiatives are in place to facilitate teacher professional learning in digital technologies. For example, The Computer Science Education Research Group (CSER, n.d.) provides professional learning related to the new Digital Technologies curriculum through the Next Steps Massive Open Online Course (MOOC). Teachers are also supported by CSER through social media conversations and a National Lending Library providing classroom resource kits. Additionally, the Digital Technologies Hub (Digital Technologies Hub, n.d.) is available to support teachers as they implement the Digital Technologies curriculum, as is Scootle (Scootle, n.d.), another national digital repository set up to provide resources aligned to the Australian Curriculum. Finally, teachers learning about STEM education and digital technologies can access the STARportal (Australian Government, n.d.), Australia's centralised national portal for STEM activities. The next section addresses STEM education in the context of Australian teachers and their workplaces.

2.2. STEM Education in Australia

The Australian Curriculum, including the areas of science and mathematics education, is another aspect of change for Australian teachers. Science and mathematics education are pulled under the umbrella term of Science, Technology, Engineering and Mathematics (STEM) education, described as the solution to many problems surrounding the global, knowledge-based economy (ACARA, 2016). STEM education requires new and complex learning skills. In this section the literature on STEM education, related to the context of this study, is presented. It begins with a definition of STEM education. The current Australian government's agenda for STEM education is then outlined, followed by a description of STEM as it is presented in the Australian Curriculum. Problems faced by teachers implementing STEM are discussed and suggestions for two alternative integrated STEM approaches are given.

2.2.1. Defining STEM in the Australian Education Context

STEM is defined as "learning and/or work in the fields of Science, Technology, Engineering, and Mathematics, including preliminary learning at school prior to entry into the specific disciplines" (Freeman et al., 2016, p. 3). Further, with reference to school learning, the National STEM School Education Strategy describes STEM education as "a cross-disciplinary approach to teaching that increases student interest in STEM related fields and improves students' problem solving and critical analysis skills" (Education Council, 2015, p. 5). The Education Council (2018a) refers to STEM education as "the teaching of the STEM disciplines, as well as an integrated approach that increases interest and knowledge in STEM disciplines and improves students' problem solving and critical analysis skills" (p. 19). With reference to the above quote, STEM disciplines are Science (physics, chemistry, biology, earth and environmental science), Technology, Engineering and Mathematics (Education Council, 2018a).

An integrated approach to STEM education involves teaching concepts and skills from the disciplines of Science, Technology, Engineering, and Mathematics within a framework of critical and creative thinking, ethical decision making and collaboration (Taylor, 2016). However, little information is available in the literature regarding how teachers can be supported to adapt to curriculum change as they learn about teaching a contemporary and interdisciplinary STEM curriculum. According to Blackley and Howell

(2015), the emergence of STEM was driven by a political agenda "grounded in vocational and economic imperatives" (p. 104). Within the context of this agenda, results of international, standards-based tests (TIMMS and PISA), and low participation rates of students in mathematics and science (Marginson et al., 2013), continue to drive reform in STEM education. Declining student participation and performance in STEM subjects across Australia once elicited conversations of a 'crisis' in STEM education (Office of the Chief Scientist, 2013), whereas now, there is more emphasis on innovation and entrepreneurship (Australian Government, 2015).

2.2.2. STEM Initiatives

The Australian Government seeks to improve student participation and performance in STEM through the National Innovation and Science Agenda (Australian Government, 2015). This agenda includes a range of *Inspiring all Australians in digital literacy and STEM initiatives* being introduced for the benefit of students and teachers (Australian Government, website, n.d.). The National STEM School Education Strategy was endorsed in 2015 (Education Council, 2015) to coordinate STEM education initiatives. To improve the engagement and attainment of Australian students in STEM, the government proposes to increase the capacity of teachers and the quality of their STEM teaching (Education Council, 2015). Quality teaching is linked to increasing the engagement and performance of students in STEM education, while capacity is related to equipping teachers with the skills and confidence to facilitate this (Education Council, 2015). In doing so, the government recognises the challenges of "the rapidly changing nature of technology, and the importance of real-world approaches to science education" (Education Council, 2015, p. 8) and the inequalities that exist for "girls, students from low socio-economic status backgrounds, Aboriginal and Torres Strait Islander students, and students from non-metropolitan areas" (Education Council, 2015, p. 4).

2.2.3. STEM in the Australian Curriculum

The Australian Curriculum is a multi-dimensional curriculum that combines disciplinary knowledge, skills, and understanding with general capabilities and cross-curricular priorities (ACARA, n.d.-a). STEM is not a specific learning area in the Australian Curriculum; however, it is addressed through the learning areas of Science, Design and Technologies, Digital Technologies and Mathematics, and certain aspects of the capabilities

and priorities dimensions (ACARA, n.d.-d). Throughout this thesis I will refer to these broad learning areas, and the subjects within them (e.g., Chemistry) as STEM subjects. The general capabilities include ICT and development of higher-order abilities such as critical thinking, social capabilities, and ethical understanding (ACARA, n.d.-b). The cross-curriculum priorities include an understanding of sustainability, indigenous history and culture, and engagement in Asia (ACARA, n.d.-b), enabling teachers and students to consider different contexts and world views related to STEM education (Taylor, 2016). The Engineering component of STEM is addressed throughout the Design and Technologies learning area and is often used as the context for STEM learning (ACARA, 2016; Taylor & Taylor, 2019). However, Timms et al, (2018) claim "the Australian Curriculum is not based on a modern conceptualisation of STEM" (p. 19), and recommend schools "move towards an integrated STEM curriculum" (p. 25).

According to Blackley and Howell (2015), successful implementation of STEM education is related to curriculum structure. In other words, schools and teachers may adopt a single discipline (non-integrated) and/or cross-disciplinary (integrated) approach to STEM education (Education Council, 2015). Adopting a non-integrated approach can mean several things, for example, teaching individual subjects in isolation, particularly science (English, 2016; Kennedy & Odell, 2014; Sanders, 2009), and assessing students in limited ways related to science understanding and inquiry skills only (Taylor, 2018). However, with reference to STEM learning areas, Sanders (2009) believes STEM education means "a lot more than a four-letter word to bring them together" (p. 21). Similarly, Rosicka (2016) describes STEM education as more than just "the sum of its parts" (p. 4). An integrated approach means teaching STEM subjects with an emphasis on connections between them, but also enabling students to develop further understanding through application of their knowledge to genuine problems that exist beyond the classroom (Rosicka, 2016; Taylor, 2018). This approach to teaching STEM subjects is seen as "a way of engaging students in authentic tasks and innovation" (Tytler et al., 2019, p. 51).

However, not all STEM subjects are integrated in the same way. According to Tytler et al. (2019) "STEM is predominantly the province of mathematics and science, and technology subjects" (p. 52). However, to Sanders (2009), STEM education means integrating any two or more STEM subjects, and/or integrating a STEM subject with other

subject areas. Additionally, the Arts is a component often included in Science, Technologies, Engineering, the Arts and Mathematics (STEAM) education programs (English, 2017; Taylor & Taylor, 2019). Taylor (2018), for example, talks of integrating the Arts with STEM subject areas (STEAM) in response to the need to prepare students for "global crises that are impacting the economy, the natural environment and our diverse cultural heritage" (p. 1). Another example is the use of aesthetics to include the Arts, since it has a role in the design and construction of famous bridges (English, 2017). Therefore, STEM integration may refer to how many and which subjects are integrated (English, 2016), curriculum cutting across traditional boundaries (Kennedy & Odell, 2014), and engaging more students in real-world issues (Kennedy & Odell, 2014). Nevertheless, throughout this thesis, I use the term "STEM education" to mean the teaching of STEM subjects through an "integrated approach" (Education Council, 2018a, p. 19).

Regardless of which approach is taken, STEM initiatives in schools can be problematic (Blackley & Howell, 2015), and challenging (Ng & Chan, 2018). For example, the core concepts and skills of all STEM subject areas are not represented equitably (English, 2016); teachers may not be confident in teaching mathematics and/or science which makes STEM integration difficult (Rosicka, 2016); and science teachers may find it difficult to facilitate development of their students' higher order abilities as required by the Australian curriculum (Taylor, 2016). Additionally, teachers may not have a clear picture of what integrated STEM means and how it should be taught (Ring-Whalen et al., 2018). Since teachers' conceptions of integrated STEM have an impact on the lessons they create, different conceptions result in different classroom practices (Ring-Whalen et al., 2018).

Teachers may also be expected to teach outside their specialist areas - known as "out of field teaching" (Timms et al., 2018, p. 17; Weldon, 2016). Weldon (2016) reports "about 26 per cent of teachers at Years 7 - 10 are teaching a subject in which they have not specialised as part of their teaching load, as are about 15 per cent of teachers at Years 11 - 12" (p. 1). Apparently, early career teachers are teaching out-of-field more often than experienced teachers (Weldon, 2016). In fact, concerns exist regarding the availability of qualified teachers for STEM subject areas overall (Timms et al., 2018). Added to this problem is the isolation Australian teachers can face in the workplace. Not only can the experience of teaching in remote schools be challenging (Lock et al., 2012), but there is also a shortage of

teachers willing to work in rural and regional areas of Australia (Kline et al., 2013). However, what is promising is increased connectivity to peers and resources enabled by the use of information and communications technology (ICT). This is one aspect of teachers' experience of professional learning explored in this study.

In the next section of this literature review I explore two different classroom practices that could be viewed as taking an integrated/cross-disciplinary approach to STEM education. They are examples of how teachers, and their students, can use the global, social, and participatory nature of the open Web to learn in areas that are relevant to STEM education, and the Australian Curriculum.

2.2.4. New Approaches to STEM Education

STEM education is described as "a cross-disciplinary approach to teaching that increases student interest in STEM related fields and improves students' problem solving and critical analysis skills" (Education Council, 2015, p. 5). However, the literature explored above reveals there is no consistent understanding of, or approach to, STEM education to guide teacher practice in the classroom. Indeed, despite the Government's enthusiasm to introduce integrative STEM initiatives into schools, educational research in this area is lacking (Blikstein et al., 2017). However, what follows is a review of two movements that could be viewed as taking a contemporary, cross-disciplinary approach to STEM education, the *citizen science* movement, and the *maker* movement.

The Citizen Science Movement. The Australian Citizen Science Association (ACSA) defines *citizen science* as "public participation and collaboration in scientific research with the aim to increase scientific knowledge" (ACSA, n.d.). *Citizen science* is also described as inquiry, involving different activities across scientific disciplines, where citizens work in isolation and/or collaboration with professional scientists (Strasser & Haklay, 2018). People engage in practical, authentic, problem solving experiences and further develop their subject knowledge and skills (Pecl et al., 2015). However, Strasser et al. (2018) question if there is a thing called *citizen science*, whether it is a "coherent whole, let alone a cohesive social movement" (p. 2). Regardless of how *citizen science* is defined, it is recognised as a "flexible concept which can be adapted and applied within diverse situations and disciplines" (ACSA, n.d.). Could it be adapted and applied to integrated STEM education?

Since there is no clear definition of *citizen science*, one way to understand *citizen science* projects is through the different ways new knowledge is produced. Strasser and Haklay (2018) list "five epistemic practices involved in participatory research - *sensing, computing, analysing, self-reporting and making*" (p. 7). Sensing refers to people recording and uploading biological and/or physical observations of their local environments, often using smartphone applications, for example, FrogID (Australian Museum, n.d.), a project mapping Australia's frogs. Computing refers to people volunteering the processing power of their computers to large scale projects such as Rosetta@home (University of Washington, n.d.), a project about the design and shapes of proteins. Many projects require people to analyse existing scientific data, for example, Galaxy Zoo (Zooniverse, n.d.), a project where images are analysed to classify galaxies. Citizens can *self-report* personal data, for example, CSIRO Energise (Commonwealth Scientific and Industrial Research Organisation [CSIRO], n.d.-a), a project using pooled data to research household power usage. Finally, citizens produce new knowledge through *making* artefacts, a movement described in more detail in the next section.

Citizen science engages people in scientific inquiry in different ways. It encourages teachers and students to ask questions, gather evidence, analyse data, develop explanations, and communicate with others, across a range of disciplines, beyond the classroom walls. However, the role of *citizen science* in K-12 classroom is under explored (Shah & Martinez, 2016). There is little research related to *citizen science* and student outcomes (Bonney et al., 2016) and, more generally, *citizen science* integration into schools (Paige et al., 2015; Shah & Martinez, 2016). Nevertheless, *citizen science* could be a new and different approach to integrated STEM education.

The Maker Movement. Like *citizen science*, there is no clear definition of the *maker* movement in the literature; however, different ways of conceptualising this movement are emerging (Rosa et al., 2017). In a general sense, the *maker* movement "is made up of a community of makers, who gather in makerspaces to take part in a common activity: making" (Davis et al., 2017, p. 175). People involved in the *maker* movement focus not only on making artefacts but working with "ideas that give meaning to those things" (Gilbert, 2017, p. 84). Therefore, making is about turning ideas into reality (Davis et al., 2017), and the creative production of meaningful artefacts (Halverson & Sheridan, 2014).

Making ranges from traditional arts and crafts activities, such as woodwork, to STEM activities such as robotics (Rosa et al., 2017). This occurs in both physical and/or digital makerspaces where makers share the processes and products of making with others (Halverson & Sheridan, 2014). What is different about making and creating in contemporary society is that people can use computers to design their artefacts, then use digital fabrication tools and materials to create their artefacts in physical form. In other words, they are taking the "programmability of the digital worlds which we invented to the physical world we inhabit" (Rosa et al., 2017, p. 4). Typical makerspaces now have tools for digital fabrication (Eriksson, et al., 2014), enabling makers to "manipulate atoms as easily as they manipulate bits" (Rosa et al., 2017, p. 4). Digital fabrication tools such as 3D printers and laser cutters (Cohen et al., 2017) are becoming increasingly powerful and accessible (Eisenberg, 2017), and available and affordable (Rosa et al., 2017). In addition to digital fabrication tools, makerspaces may be equipped with interesting materials (e.g., conductive paints and fibres), computing devices to embed in artefacts (e.g., microprocessors) and interface elements (e.g., wearable input devices) (Eisenberg, 2017). However, like *citizen science*, there is more to this movement than gaining new skills.

In both movements there is commitment to achieving something within and across global communities of like-minded people (Davis et al., 2017; Eisenberg, 2017), and a culture of participation and sharing in physical and/or virtual spaces (Halverson & Sheridan, 2014; Rosa et al., 2017). Additionally, both movements are interdisciplinary, public, and supported through digital technologies. Therefore, like *citizen science,* maker activities are seen as a promising way to engage students in interdisciplinary STEM education (Litts et al., 2017). Students in Australian schools are beginning to apply their STEM knowledge in makerspaces due to an initiative of the National Innovation and Science Agenda (Australian Government, 2015). However, despite the Government's enthusiasm to introduce integrative STEM initiatives into schools, there is limited research into the educational benefits of the *maker* movement (Blikstein et al., 2017).

As mentioned previously, the Australian Curriculum directs teachers towards threading two new dimensions throughout all learning areas, the general capabilities, and cross-curriculum priorities (Australian Curriculum and Assessment and Reporting Authority, n.d.-a). As a consequence of this curriculum directive it is hoped teachers will "develop

students as global citizens capable of not only adapting to a rapidly changing world but also participating actively in shaping it for the better" (Taylor, 2016). The *citizen science* and *maker* movements have the potential to foster these global, social, and participatory aims. However, meeting these aims could be a challenge for teachers working with an already crowded curriculum and coping with high stakes testing of their students (Mueller et al., 2012). Therefore, tapping into existing projects, aspects of which address the curriculum dimensions, could be a supportive option for teachers. These movements could offer a new and different approach to integrated STEM education.

Having reviewed the context within which Australian teachers work, followed by taking a look Australia's STEM education agenda, I now turn to literature related to teachers' professional learning.

2.3. Teachers' Professional Learning

It is widely recognised that all teachers have a significant and influential role in the classroom, where their efforts are linked to student achievement (Education Council, 2018a; Muijs et al., 2014). Therefore, the overall purpose of professional learning is often linked to teachers improving their "pedagogical practice" to support and improve student learning (Australian Institute for Teaching and School Leadership, 2012a, p. 6; Education Council, 2015, 2018a; Desimone, 2009, 2011). More specifically and with respect to student learning, the purpose of professional learning may range from teachers having a "positive influence" (Guskey, 2017, p. 33) to producing measurable improvement in student outcomes (AITSL, 2012a). With respect to teachers, the purpose of professional learning ranges from improving the "quality of teaching" (Fullan & Hargreaves, 2016, p. 1), to developing their skills and competencies as defined by professional standards (Mockler, 2013a), to changing the beliefs, attitudes, and perceptions of teachers (Guskey, 2002; Tondeur et al., 2016), and to learning continuously and life-long as a professional (Thomson & Hillman, 2019; Webster-Wright, 2009).

The professional learning of teachers is "one way to support the increasingly complex skills students need to learn" (Darling-Hammond et al., 2017, p. v). However, while writing this section on professional learning, I keep in mind Taylor's (2015) pertinent question: "How can we prepare science teachers with professional knowledge and skills for ensuring that teaching and curricula meet the global challenges of the 21st century?" (p. 1079). Currently,

Australian teachers of STEM subject areas are not required to undertake specific professional learning related to the content and pedagogy of subjects they teach (Education Council, 2018a, 2018b). Since the professional learning literature related specifically to K-12 teachers involved in STEM education is limited, this review of the professional learning literature relates to K-12 teachers overall, with examples of specific studies related to the area of STEM education. Firstly, I begin with a review of how the terms professional development and professional learning are discussed in the K-12 professional learning literature. This is followed by a brief outline of the different approaches of K-12 teachers' professional learning, then the specific features of professional learning that are relevant to this study, including Professional Learning through Open Education (PLOE).

2.3.1. Professional Learning or Professional Development?

The term professional development often refers to the activities teachers engage in that may lead to professional learning (Boylan et al., 2018; Webster-Wright, 2009). These events and activities are also referred to as "professional development experiences" (Guskey, 2002, p. 381) of various types, for example, they may be formal, informal, externally provided, and/or job-embedded (Darling-Hammond et al., 2017). On the other hand, Fullan and Hargreaves (2016) view professional development as "growth" with respect to who teachers are and what they can do, that occurs through a range of different activities (p. 3). To Avalos (2011) professional development "is about teachers learning, learning how to learn, and transforming their knowledge into practice for the benefit of their students' growth" (p. 10). To complicate matters, there is recognition that professional development activities that are provided and directed by others may or may not lead to teacher learning (Beswick et al., 2016; Bobis et al., 2020), "despite its intent" (Darling-Hammond et al., 2017, p. 1). As with professional development, there is variation in how professional learning is defined in the literature.

Professional learning may be understood as teachers "learning something new that is potentially of value" (Fullan & Hargreaves, 2016, p. 3). Value in this sense means ensuring that professional learning has an impact on student achievement and their social and emotional learning (Fullan & Hargreaves, 2016). Alternatively, professional learning can be seen as a "journey" towards "getting better" at influencing student learning (Guskey, 2017,

p. 33). The Australian Institute for Teaching and School Leadership defines professional learning as:

> …the formal or informal learning experiences undertaken by teachers and school leaders that improve their individual professional practice, and a school's collective effectiveness, as measured by improved student learning, engagement with learning and wellbeing. At its most effective, professional learning develops individual and collective capacity across the teaching profession to address current and future challenges. (AITSL, 2012b, p. 2)

This definition refers to professional learning as an experience and differentiates formal and informal experiences. It also broadens the concept of value into the realm of measurement and effectiveness to the level of the collective. To Darling-Hammond et al. (2017) professional learning is a product "of both externally provided and job-embedded activities that increase teachers' knowledge and help them change their instructional practice in ways that support student learning" (p. 2). This understanding of professional learning brings in the notion that teachers' learning emerges from the knowledge of other people, or through knowledge generated through their own practice in the classroom context. This latter form of teacher professional learning is referred to as *practice-based learning* (Zepeda & Ponticell, 2018, p. 513).

Professional learning is described in the literature as a process that teachers engage in, and learn from, through which they expand, refine, and change their practice (Lieberman & Pointer Mace, 2010; Mockler, 2015), change their beliefs and knowledge (Bobis et al., 2020), and "acquire new knowledge, skills, affects or behaviours" (Beswick et al., 2016, p. 330). Alternatively, professional learning can be understood more from the perspective of teachers and defined as learning that results from any experience where teachers themselves consider they have learned something related to their roles as teachers (Webster-Wright, 2009). In fact, professional learning is a more appropriate term if quality learning experiences for teachers foster "reflective practice, critical thinking and continuing learning" (Bobis et al., 2020, p. 118). Overall, professional learning is recognised as a complex process (Avalos, 2011; Boylan et al., 2018; Opfer & Pedder, 2011). To avoid confusion, throughout this thesis I will use professional learning as a "generic" term to represent the activities/approaches teachers undertake and/or the learning they experience from these activities, assuming that not every

activity will lead to professional learning (Bobis et al., 2020, p. 118). In the next section of this literature review the different approaches to K-12 teachers' professional learning are described.

2.3.2. Approaches to K-12 Teachers' Professional Learning

There are many different approaches to teachers' professional learning (Bobis et al., 2020; Borko, 2004; Desimone, 2011; Education Council, 2018b). According to a survey conducted by the Australian Institute of Teaching and School Leadership (AITSL, 2017), some professional learning experiences were shown to be more commonly accessed by K-12 teachers' than others. In the 12 months prior to the AITSL (2017) survey, 75% or more of the teachers accessed "discrete courses externally or in the school; professional reading; online learning; and professional conversations on teaching and learning" (AITSL, 2017, p.6). In the same time period, 50% of the teachers engaged in "observation and feedback; coaching or mentoring; network conversations; reading or conducting research" (AITSL, 2017, p.6). In the professional learning literature, activities are classified as being formal and/or informal; individual and/or social; mandatory and/or voluntary; structured and/or unstructured; and/or located online, external to schools and/or embedded in practice (Desimone, 2011). Professional learning activities are also categorised according to the effectiveness of specific design features (Darling-Hammond et al., 2017; Desimone, 2009, 2011; Desimone & Garet, 2015), or their underlying conceptual models (Boylan et al., 2018; Kennedy, 2014).

It is beyond the scope of this literature review to cover the professional learning activities of K-12 teachers from every angle. Therefore, in the next section learning metaphors are used as an organising framework to provide clarity and focus for this review of the literature on teachers' professional learning.

2.4. Conceptualising Teachers' Professional Learning Through Learning Metaphors

Metaphors are often used to conceptualise, describe and communicate abstract concepts such as the phenomenon of learning (Boud & Hager, 2012; Elkjaer, 2004; Sfard, 1998, 2009b). For instance, Sfard (1998, 2014), who has a professional background in mathematics education, conducts research into the relationship between thinking and communication in the area of mathematics education, and focuses on "basic metaphors rather than on particular theories of learning" (Sfard, 1998, p. 4). Sfard's (1998) basic metaphors of

learning are the acquisition metaphor ("learning-as-acquisition") and the participation metaphor ("learning-as-participation") (Sfard, 2009a, p. 55). However, Sfard (1998) reminds her readers that neither the acquisition or participation metaphors are sufficient to "cover the entire field" (p. 12). Thus, the creation metaphor is a third metaphor used in the literature to conceptualise learning (Karlgren et al., 2020, p. 3). In this section I discuss the common metaphors used in the literature to conceptualise learning generally, and relate the use of metaphors to the context of K-12 teachers' professional learning. Table 2.1. below provides an advance organiser for the reader that shows the learning metaphors, and the sequence in which they are discussed in the following sections.

Table 2.1

Learning Metaphors used to Conceptualise K-12 Teachers' Professional Learning, and the Sequence in which they are Discussed

Learning Metaphors
2.4.1. Learning as Acquisition
Emphasis of the metaphor
Acquisition and teachers' professional learning
Effective professional learning
Limitations to effectiveness approaches to professional learning
Effective professional learning - content focus
Effective professional learning - coaching
Effective professional learning - reflection and feedback
2.4.2. Learning as Participation
Emphasis of the metaphor
Communities
2.4.3. Learning as Creation
Emphasis of the metaphor
Experience and practitioner inquiry
Scholarship of teaching and learning
Lesson studies and Learning studies - content focused professional learning

2.4.1. Teachers' Professional Learning as Knowledge Acquisition

The emphasis of this metaphor is on individuals acquiring knowledge (Sfard, 1998, 2009a; Schatzki, 2017). It is a "common sense" view of learning (Boud & Hager, 2012, p.18) that focuses on the mind of an individual and what moves "into it" (Sfard, 1998, p. 6). The mind is viewed as a "container" to be filled with knowledge (Sfard, 1998, p. 5). Cognitivists assume that learners acquire knowledge through the formation of "representations" in their minds of phenomena that exist in the world (Korthagen, 2017, p. 531). Constructivists, on the other hand, accept that the real world exists, and that learning is an internal "mental activity" (Ertmer & Newby, 2013, p.55; Sfard, 1998), but assume that the knowledge learners acquire is a constructed representation of the real world (Biesta & Vanderstraeten, 1997; Billett, 1996; Sfard, 1998). To Biesta and Vanderstraeten (1997) constructivism is a "theory of knowledge acquisition" (p. 1).

Learners construct their own knowledge of the world by interpreting and finding meaning in their own experiences (Ertmer & Newby, 2013; Land & Jonassen, 2012). This process is influenced by the learner's prior knowledge, skills and thoughts, and the social, cultural, historical and physical contexts in which their learning is situated (Billett, 1996; Lave, 1993; Putnam & Borko, 1997, 2000). Social constructivists, for instance, emphasise the social influence on the meaning making process (Ernest, 1994; Land & Jonassen, 2012). In addition to these influences, it is assumed that acquired knowledge can be transferred to new situations (Karlgren et al., 2020; Korthagen, 2017; Sfard, 1998), applied in different contexts (Ertmer & Newby, 2013), and shared with other people (Sfard, 1998).

This cognitive and constructivist understanding of the acquisition metaphor is used to conceptualise the professional learning of K-12 teachers in which teachers are assumed to be "passive recipients of knowledge" transmitted to them, and/or "active and reflective learners" who construct meaning from their experiences (Kelly et al., 2019, p. 86). An assumption underpinning the acquisition metaphor is that teachers need updating because they are deficient in certain skills and knowledge (Boud & Hager, 2012; Forde & McMahon, 2019). One way to update teachers is through the more formal "training" or "deficit" models of professional learning (Kennedy, 2014, p. 6) through which other people, or "experts" select and transmit new knowledge to teachers (Boud & Hager, 2012, p. 20; Cochran-Smith &

Lytle, 1999; Putnam & Borko, 1997). This is a common approach to teachers' professional learning.

The "knowledge base" teachers need to acquire is generated through systematic, scientific research and is the evidence upon which their teaching practice should be based (Biesta, 2010; Cochran-Smith & Lytle, 1999, p. 259). Evidence-based teaching is said to occur when teachers implement the "practices that have been shown to be effective in controlled research studies" (Masters, 2018, p. 4). Teachers often acquire this new knowledge about effective practice independently of the context within which they work, transfer it to their classrooms then apply it to their teaching (Boud & Hager, 2012; Cochran-Smith & Lytle, 1999). This linear transmission of skills and knowledge is a common assumption associated with the acquisition metaphor (Hakkarainen & Paavola, 2009). Another assumption is that effective practice will improve the learning outcomes of students (Desimone, 2009, 2011; Guskey, 2002). However, there are different interpretations of the term effectiveness in the literature.

'Effectiveness' Approaches to Teachers' Professional Learning. Effective professional learning is commonly described in terms of specific design features of the professional learning approaches, or in terms of the impact of different learning approaches on teachers' knowledge, classroom practices, and student achievement (Desimone, 2009, 2011; Darling-Hammond et al., 2017; Kraft et al., 2018; Kennedy, 2016). The language of change is also used in the literature to describe the effectiveness of professional learning, for example, when it leads to changes in the practices of teachers (Whitworth & Chiu, 2015), and/or changes in the beliefs and attitudes of teachers (Tondeur et al., 2016). Regardless of how effectiveness is defined, a vast body of literature focuses on the effectiveness of professional learning for K-12 teachers (Desimone & Garet, 2015; Opfer & Pedder, 2011). Despite much of the research originating in the United States, Desimone and Garet (2015) claim its findings apply to other countries. I have drawn upon this literature due to the dearth of research into the professional learning of Australian K-12 teachers (Kelly et al., 2019).

From this research a range of features of effectiveness have emerged, showing positive links between professional learning activities, the practices of teachers, and the outcomes of students (Darling-Hammond et al., 2017; Desimone, 2009, 2011; Desimone & Garet, 2015). There is consensus on seven evidence-based, core features or "design elements"

of effective professional learning approaches, often combined in different ways, commonly reported in the professional learning literature (Darling-Hammond et al., 2017, p. 23). Effective professional learning approaches:

- are content focused
- incorporate active learning strategies
- engage teachers in collaboration
- use models and/or modelling
- provide coaching and expert support
- include time for feedback and reflection
- are of sustained duration (Darling-Hammond et al., 2017, p. 23).

However, empirical research shows that many professional learning approaches with the recommended design elements are ineffective in facilitating change in teachers' knowledge, practice, and/or student learning (Desimone & Garet, 2015; Darling-Hammond et al., 2017; Hammond & Moore, 2018; Kennedy, 2016; Opfer, 2016; Kraft et al., 2018).

There are several reasons reported in the relevant literature for why the effectiveness of research-based approaches to teachers' professional learning is limited. Studies confirm the difficulty of translating general design elements/features of professional learning into "effective practice" (Desimone & Garet, 2015, p. 253). It is suggested these features may not be "specific enough" to guide how professional learning experiences are designed (Borko, 2019, p. 142; Osborne, et. al., 2019, p. 1076), and the subsequent delivery of the activities may differ to how they are designed (Desimone, 2018). For example, sustained duration of an activity is a design feature identified for effective professional learning, yet teachers often experience "short-term courses or single workshops" (Gomez Zaccarelli et al., 2018, p. 30). There are also difficulties in scaling up and sustaining research based professional learning approaches (Kraft et al., 2018, p. 2; Mockler, 2013a). Even if they are "implemented at-scale" the failure of professional learning activities to improve the practices of teachers, or the achievement of students, continues (Kraft et al., 2018, p. 2). Finally, the generic nature of professional learning activities may ignore factors that have an impact on effectiveness, such as the different experiences of individual teachers and the school contexts within which their work is situated (Beswick et al., 2016; Desimone, 2018). Overall, the

design elements of effective professional learning are considered "necessary but not sufficient to effect change" (Borko, 2019; Osborne et al., 2019, p. 1069).

In the next section I take a closer look at three 'effective' professional learning approaches that: are content focused, involve coaching, and include time for feedback and reflection (Darling-Hammond et al., 2017).

'Effective' Content-focused Professional Learning. Research evidence pointing to the effectiveness of content focused professional learning is inconclusive (Garet, et al., 2016; Yang et al., 2020). Never-the-less it has been shown that when the content of teaching is linked with pedagogical support, professional learning is more effective (Darling-Hammond et al., 2017). When the experiences of teachers are considered, from their perspective, a different picture emerges. For example, from the perspective of Australian primary and lower secondary teachers who participated in the Teaching and Learning International Survey, 2018, content focussed professional learning is perceived to be the most effective (Thomson & Hillman, 2019). In this instance, content focussed professional learning refers to approaches that "built on teachers' prior knowledge" or "provided an opportunity to apply new ideas/knowledge in the teacher's own classroom" (Thomson & Hillman, 2019, p. 109). These findings suggest that research conducted from the perspective of teachers can add to an overall understanding of their professional learning. It is for this reason that my study is conducted from the perspective of teachers themselves.

This knowledge of content-focused professional learning supports Kyndt et al's. (2016) systematic review of literature on K-12 teachers' informal professional learning activities and outcomes. They found that teachers were particularly motivated to acquire knowledge of subjects, pedagogy and skills that are "practical, relevant, useful, and meaningful for their own classroom" (Kyndt et al., 2016, p. 1130). Since content knowledge is perceived by teachers to be meaningful, it is surprising that teachers of STEM subject areas are currently not required to undertake specific professional learning related to the content and pedagogy of subjects they teach (Education Council, 2018a, 2018b). As a need identified by teachers themselves, it should be linked to their professional learning (Darling-Hammond et al., 2017).

The content knowledge of K-12 teachers is commonly reported in the literature in the context of two constructs, "Pedagogical Content Knowledge" (PCK) (Putnam &

Borko, 1997; Shulman, 1986, p. 6), and "Technological Pedagogical Content Knowledge" (TPACK) (Mishra & Koehler, 2006, p. 1017; Warr et al, 2020). Shulman (2011) refers to PCK as "a special kind of knowledge" where subject knowledge overlaps with pedagogical knowledge (p. 5). Mishra and Koehler (2006) built upon PCK to describe the new skills and knowledge teachers need to acquire in order to teach effectively with technology (Koehler & Mishra, 2009). Their research formed the construct of "Technological Pedagogical Content Knowledge" (TPACK) (Mishra & Koehler, 2006 p. 1017; Warr et al., 2020). However, Warr et al. (2019) claim the TPACK framework has had little impact, at scale, on the use of technology in education. They recognise that integration of the TPACK framework into the classroom needs to focus more on "complex and situated nature of teaching" (Warr et al., 2019, p. 2561).

Coaching for 'Effective' Professional Learning. Educational researchers are becoming more aware that teachers' professional learning and knowledge acquisition is more effective when situated in the context of their daily practice (Bobis et al., 2012; Evans, 2019; Korthagen, 2017). In the workplace the social aspect of learning through acquisition occurs when individuals acquire the knowledge that others have (Greenhalgh & Koehler, 2017). Knowledge acquired through social construction is still possessed by the individual who interprets and makes meaning from the experience (Land & Jonassen, 2012). One of the social and 'effective' professional learning approaches that occurs in the context of daily practice is coaching (Darling-Hammond et al., 2017). Coaches observe teachers and offer feedback (Kraft et al., 2018); transfer skills and knowledge to them (Ehsanipour & Zaccarelli, 2017); support and guide teachers as they implement new tools and share knowledge about evidence-based practices (Darling-Hammond et al., 2017). However, there is a lack of empirical evidence to support the improvement of teacher practice through coaching (Desimone & Pak, 2017). Teachers need to be interested and willing to be observed by coaches, to experiment, take risks, and receive feedback that may be critical (Kraft et al., 2018). There is also a problem with cost and scalability, and when coaching moves into digital environments research has shown "no difference between the effectiveness of in-person and virtual coaching" (Kraft et al., 2018, p. 31).

Reflection and Feedback for 'Effective' Professional Learning. Reflecting on experience and receiving feedback from others are concepts common to theories of adult learning (Brookfield, 2005; Darling-Hammond et al., 2017). My interest lies in the meaning teachers attribute to their professional learning experiences and literature in the field of adult learning speaks more of meaning than the effectiveness of experience (Mezirow, 1990). From the perspective of transformative learning theory, adults learn by interpreting their experiences through their unique combinations of assumptions and expectations, or "meaning perspectives" (Mezirow, 2009, p. 92). By interpreting and finding meaning in their experiences, adults construct knowledge of the world (Ertmer & Newby, 2013; Land & Jonassen, 2012). This meaning is seen as learning if the adult's interpretation guides their "decision-making or action" (Mezirow, 1990, p. 1).

It is well known that teachers' learning is influenced by their existing knowledge, prior experiences, beliefs, attitudes, and values (Cochran-Smith & Lytle, 1999; Ertmer & Newby, 2013; Putnam & Borko, 1997). Additionally, beliefs are known to influence the acquisition and interpretation of knowledge, are resistant to change, and have a strong effect on behaviour (Pajares, 1992). However, meaningful change can occur when adults reflect on their own assumptions and practices they have always taken-for-granted (Brookfield, 2005; Mezirow, 1990; Putnam & Borko, 1997). In the previous section it was noted that teachers need to be willing to receive feedback from coaches who may be critical of their practice (Kraft et al., 2018). For meaningful change to occur, teachers could be supported to reflect on their taken-for-granted assumptions and practices that underpin the critical feedback coaches may want to offer. A reflection strategy teachers can learn from is to analyse video recordings of themselves, and others, while teaching (Hollingsworth & Clarke, 2017).

The key points from the literature in this section are that the recommended design elements of effective professional learning are necessary but not enough to effect change in teachers' knowledge and practice; that research conducted from the perspective of teachers can add to an overall understanding of their professional learning; and that research needs to focus more on the complex and situated nature of teaching. In the next section the metaphor used to conceptualise learning is more about the learner participating in activities than acquiring something individually and/or socially (Sfard, 1998).

2.4.2. Teachers' Professional Learning as Participation

Participation or "learning-as-participation" is the second metaphor found in the literature used to conceptualise learning (Sfard, 2009a, p. 55). An assumption is that learning is not located in the minds of individuals, but in their relationships with the world (Wenger, 2010). This metaphor is understood more from a situated perspective in contrast to the cognitive perspective of learning underpinning the acquisition metaphor (Borko, 2004; Cobb & Bowers, 1999). From this perspective, learners participate in the cultural practices/ activities of a community (for example, the cultural practices of the science department in a school), and become more knowledgable through their activities (Borko, 2004; Karlgren et al., 2020; Sfard, 1998, 2009a). The contextualised and social nature of learning is prominent in the use of this metaphor (Karlgren et al., 2020; Sfard, 1998, 2009a). A framework for conceptualising the social nature of learning is the "social theory of learning" (Wenger, 2009, p. 211).

The framework integrates four aspects of learning: learning as doing (practice); learning as becoming (identity); learning as experience (meaning); and learning as belonging (community) (Wenger, 2009, p. 211). For example, a science teacher learns through the activities he/she participates in (practice), learns through belonging to the science department in a particular school (community); learns to become a more experienced teacher/perhaps a science coordinator, over time (identity); and learns through interpreting his/her daily experiences of teaching (meaning). The activities people participate in to learn are "historically established" (Qvortrup & Wiberg, 2016, p. 327). For example, the pedagogical practices teachers currently use in their classrooms originated in the early 1900s through the work of educational scholars such as John Dewey (1938). Learning these practices is more than acquiring skills and knowledge, it means becoming a competent member of a community of practitioners (Wenger, 2009; Sfard, 1998). Additionally, the meaning learners attribute to the experiences they participate in is seen as more than cognitive constructs in their minds, but includes all aspects of their experience, including relationships with others in a community they belong to (Wenger, 2010). It is this community component of the framework that corresponds to the concept of "communities of practice" that is of particular interest for this study (Wenger, 2009, p. 211).

Participation and Communities. This concept is applied to the learning of adults in many areas, for example, in education and business (Wenger-Trayner, E. & Wenger-Trayner, B., 2015), and is widely used in the professional learning literature. A community of practice originally referred to the "community that acts as a living curriculum for the apprentice" (Wenger-Trayner, E. & Wenger-Trayner, B., 2015, p. 4). It was seen as the cultural-historical context that the social process of learning was situated in (Farnsworth et al., 2016). This understanding of a community of practice suggests that it is not an organisational structure to be "designed, created, and controlled" (Henderson, 2015, p. 132). In education, communities of practice for professional learning have become "fashionably popular" (Mockler, 2013a, p. 43), despite the Wenger's (2010) awareness that "designed" communities can fail (p. 193). A commonly mentioned reason is the lack of attention paid to power relationships that exist between members of a community (Henderson, 2015; Wenger, 2010). Professional learning communities (DuFour & Eaker, 1998) are a similar model, but seen more as a *"strategy for sustained, substantive school improvement"* (p. xi) rather than an "environment of important learning" that should typify communities of practice (Wenger, 2009, p. 207). Regardless of model, the concept of a community for professional learning is a popular one, both offline and online (Henderson, 2015). In the next section I review the literature related to the creation of new knowledge during the social and cultural practices of participating in professional learning activities.

2.4.3. Teachers' Professional Learning as Knowledge Creation

"Knowledge-creation" is a third metaphor of learning (Hakkarainen & Paavola, 2009, p. 74; Karlgren et al., 2020). This metaphor conceptualises learning in contemporary society in which increasing demands are placed on students and workers to communicate and collaborate, to be creative, innovative, productive, and digitally literate (Karlgren et al., 2020). Knowledge creation means more than acquiring knowledge or becoming more knowledgable through participating in social activities. It refers to the deliberate, collaborative processes of adding value to and advancing knowledge through the production of new ideas that are public and embodied in artifacts (Bereiter & Scardamalia, 2014, 2016; Karlgren et al., 2020). There are a range of approaches (different literatures) that foreground the process of knowledge creation. This metaphor appears in the organisational literature on Knowledge Creation (Nonaka & Takeuchi, 1995), and in the educational literature on

Knowledge Building (Bereiter & Scardamalia, 2003) and Trialogical Learning (Paavola & Hakkarainen, 2005). Although not explicitly called knowledge creation, this metaphor is implicit in the areas of literature related to knowledge creation by teachers, for teachers, from the experience of teaching such as Practitioner Inquiry (Cochran-Smith & Lytle, 2004), and the Scholarship of Teaching and Learning (Boyer, 1990; Shulman, 2001, 2011). It is these areas of literature that are reviewed in the following sections.

Knowledge Creation Through Experience and Practitioner Inquiry. Previously I discussed the assumption that teachers need to acquire, and base their teaching on, formal, generalisable, knowledge produced through systematic, scientific research. However, Shulman (2000a) made a point that teachers "know a great deal more about teaching than our theories can yet account for" (p. 134). Schon (1995) was aware of this knowledge "embedded in competent practice" with reference to his study of practitioners who work in complex situations (p. 29). This certainly includes teachers who consistently demonstrate their ability to deal with the complex nature of teaching (Opfer & Pedder, 2011). This knowledge is revealed through the way teachers do things every day, such as judging situations, making decisions and taking action (Cochran-Smith & Lytle, 2011; Shulman, 2007). Researchers have labelled this type of knowledge that is not easily expressed as "tacit" (Schon, 1995, p. 30); "practical" (Cochran-Smith & Lytle, 2011, p. 21); and constituting the "wisdom of practice" (Shulman, 2000a, p. 135). The classroom is a place for teachers to learn from their own experiences, and to create new knowledge from these experiences. How can this informal learning from experience be captured, made visible, shared and used by other teachers to learn from? This is certainly a relevant question for teachers around Australia who are learning about STEM education.

Professionals learning from experience in the workplace has its problems. The process is hindered by what Shulman (2016) calls "amnesia, fantasia, inertia and nostalgia" (p. 20). Amnesia is forgetting the experience; fantasia refers to having incorrect memories of the experience; inertia means not knowing what to do with the experience that was remembered correctly; and nostalgia means remembering how good things once were and not seeing a need for change (Shulman, 2016). For teachers learning from their own practice, these difficulties can be addressed by examining, analysing, reflecting on, and documenting the experience, seeking more information, and engaging in dialogue with others (Shulman,

2016). The general term for teachers participating in the study of their own practice in this way is “practitioner inquiry” (Cochran-Smith & Demers, 2010; Cochran-Smith & Lytle, 2004, p. 602; Rovio-Johansson, 2019). It is seen as research about teaching, from the perspectives of teachers themselves, for professional learning and knowledge creation (Cochran-Smith & Demers, 2010; Cochran-Smith & Lytle, 2011). This approach to knowledge creation has been around for some time.

Stenhouse (1981) argued for teachers to conduct research in education in the form of “‘systematic inquiry made public’” (p. 294). The purpose of going public was to improve the research through critique offered by others, to share it around, and add to a cumulative knowledge base (Stenhouse, 1981). Shulman (1998a) spoke of schools becoming “sites for collaborative inquiry into teaching and learning” (p. 524). Therefore, knowledge created through the experience of practitioner inquiry is situated within the context, culture and practices of its creation. Practitioners inquire into a multitude of problems related to subject areas, students, classroom practices, curriculum issues, school culture, and so on (Cochran-Smith & Demers, 2010). Additionally, this process may be supported by university researchers (Bobis et al., 2020). For example, the Coalition of Knowledge Building Schools was an initiative supported by researchers from the University of Sydney between 2001 and 2015 (Mockler, 2013b). Overall, practitioner inquiry is a participative, communal, and collegial practice of knowledge creation that is located in “problems and contexts of practice” (Cochran-Smith & Lytle, 2011, p. 20; Groundwater-Smith & Mockler, 2018). It is a form of inquiry and professional learning much broader than a short term, problem solving strategy for teachers (Cochran-Smith & Lytle, 2011; Groundwater-Smith & Mockler, 2018). In fact, practitioner inquiry is also referred to as inquiry as a stance, “a way of knowing, a frame of mind, and a worldview” (Cochran-Smith & Demers, 2010, p. 19), and is seen as an ongoing, life-long approach to professional learning (Cochran-Smith & Lytle, 2011; Groundwater-Smith & Mockler, 2018).

Practitioner inquiry is conducted for the benefit of students, teachers, schools, and the community (Cochran-Smith & Lytle, 2011), however, the transfer of local, situated knowledge to different contexts (for example, to other schools) has its limitations (Bereiter, 1997). For it to be shared and understood by teachers in different situations it needs to be reified, a term used for the “freezing” of knowledge in an artefact (Polin, 2010, p.175). In

doing so, local knowledge is "no longer bound to the situations in which it was constituted" (Bereiter, 1997, p. 303), and the artefact can be interpreted by other people in different situations (Farnsworth et al., 2016). The creation of knowledge and its representation in artefacts is also a prominent feature in the literature on the scholarship of teaching and learning (Shulman, 2016).

Knowledge Creation through the Scholarship of Teaching and Learning. The scholarship of teaching and learning literature is commonly associated with higher education despite its historical links to practitioner inquiry in the context of K-12 education (Cochran-Smith & Lytle, 2004; Hatch, 2009). President of the Carnegie Foundation for the Advancement of Teaching, Ernest Boyer (1990), explored the meaning of scholarship in the context of American Higher Education and contemporary society in his seminal work, Scholarship Reconsidered. Two of the components he included when arguing for a more flexible, modern definition of scholarship were the scholarship of discovery that refers to the process and outcomes of research, and the scholarship of teaching (Boyer, 1990). Boyer 's (1990) conceptualisation of the scholarship of teaching was further developed through the Carnegie Academy for the Scholarship of Teaching and Learning (CASTL) initiative, established by Lee Shulman and his colleagues in the late 1990's (Bergland, 2007; Hatch, 2009; Hutchings et al., 2002; Shulman, 2011). The purpose of the CASTL initiative was to promote and enhance the scholarship of teaching in K-12 schools and higher education (Hatch, 2009; Shulman, 2000b).

Shulman (1998b) argued that teaching is a form of inquiry like the scholarship of discovery (research). To be called scholarship Shulman (2011) proposed that inquiry "should be public, subject to peer review and evaluation, and accessible for exchange and use by members of one's disciplinary community" (p. 4). It is also Shulman's (2016) opinion that if learning from the experience of teaching is to be a professional learning strategy, knowledge should be captured, made visible, shared, and preserved as an "artefact of scholarship" (p. 24). Such artefacts "represent, explain, and project what we have learned in ways that others can learn from" (Shulman, 2016, p. 24). These artefacts capture new knowledge about student learning, such as how they learn from their teachers' pedagogical practices, and the difficulties they faced along the way. This makes student learning the focus of practitioner inquiry, in contrast to student test results being the measure of how effective a

practitioner's teaching is (Cerbin, 2013). It is also the focus of the word 'learning' in the term scholarship of teaching and learning (Cerbin, 2013). In the next section I present a brief review of two professional learning approaches viewed through the lens of the knowledge creation metaphor. They are classroom based, collaborative and public, where new knowledge is created through experience, captured in artefacts, and shared with other teachers.

Lesson Studies and Learning Studies - Content Focused Professional Learning. Lesson study is a model of K-12 teachers' professional learning linked to the scholarship of teaching and learning literature (Cerbin, & Kopp, 2006; Shulman, 2016). This international model of professional learning originated in Asian countries (Cerbin, 2013), and is often referred to in the literature as Japanese (Bobis et al., 2020), and/or Chinese (Shulman, 2016) lesson study. Based in schools, it is a collaborative research approach (Rovio-Johansson, 2019; Willems & Van den Bossche, 2019) through which teachers produce knowledge about their own teaching, and their student's learning (Pang & Ling, 2012). Lesson studies are a type of inquiry that involves a process of identifying a learning goal or problem, designing a lesson, reflecting, teaching, observing, analysing, and refining a lesson (Cerbin, 2013; Runesson & Gustafsson, 2012). During this public, collaborative, process teachers experience a "culture of participation" by working with and learning from each other for the purpose of improving their practice (Lieberman & Pointer Mace, 2010, p. 4).

This process described in the previous paragraph aligns with the purpose of the scholarship of teaching and learning, which is to understand the learning process, and "build a professional knowledge base for teaching, consisting of pedagogical content knowledge" (Cerbin, 2013, p. 4). Another purpose is to produce an artefact. The artefact or knowledge product of a lesson study is a lesson plan that is created in the context of a particular school and its unique culture (Runesson, & Gustafsson, 2012). This captures the process and findings of the lesson study, can be used as a teaching guide, and shared with teachers in different schools (Morris & Hiebert, 2011; Shulman, 2016). However, Runesson and Gustafsson (2012) question the transferability of a lesson plan to other school situations due to the situated nature of its creation. One way to overcome the problem of abstracting knowledge from one situation in the form of an artefact, then transferring it to another situation, is to link the inquiry with an explicit learning theory.

Similar to lesson study, learning study is another school-based research approach and collaborative model of K-12 teachers' professional learning (Rovio-Johansson, 2019). The significant difference is that learning study is underpinned by the "variation theory of learning" (Marton & Booth, 1997; Marton & Tsui, 2004; Pang & Ling, 2012, p. 589). This model also aims to improve teaching, and the learning of teachers and their students (Kullberg et al., 2020). Another aim is for teachers to become more aware of, and sensitive to, learning from the students' point of view (Pang, 2006). Once the learning problem is identified (e.g. a science concept students find difficult), a research approach called phenomenography is used to map the different ways students understand the concept (Marton, 2015; Marton & Booth, 1997; Runesson, & Gustafsson, 2012). Based on this information, the critical features of the concept students are aware of are identified (Runesson & Gustafsson, 2012). Teachers then use the principles of the variation theory of learning to design a lesson in a way that other students can become aware these critical features to improve their learning (Rovio-Johansson, 2019; Runesson & Gustafsson, 2012).

The knowledge product that emerges from a learning study is a description of the critical features and the lesson design (Runesson & Gustafsson, 2012). Like lesson studies, learning studies create new knowledge about content, for example, fractions (Lewis & Perry, 2017). This "pedagogical content knowledge" is created by teachers "through cycles of *evidence-based* classroom action" (Pang & Ling, 2012, p. 604). As a product of knowledge abstracted from a classroom situation, and reified into an artefact, it can be used as a resource by teachers in other schools to base their teaching on. This knowledge product forms a different kind of evidence to the formal "knowledge base" teachers need to acquire and base their teaching on that was described in Section 2.4.1. It is evidence about "how and why things work" in the classroom, and is created by teachers themselves, in the context of their own classrooms (Cerbin, 2013, p. 4). It can be seen as part of the broader definition of evidence-based teaching that now includes teachers not only basing their work on external research evidence but including evidence about student learning and progress that is "reliable, local" and collected by teachers themselves (Masters, 2018, p. 4).

In this section learning metaphors were used as an organiser for the purpose of reviewing the large body of literature on teachers' professional learning. It is clear from this review of that there are very different ways to conceptualise, and research, teachers'

professional learning. It is also clear that there is no conclusive evidence regarding the best approach to improving the knowledge and skills of teachers, and the learning of their students. The next section of this literature review describes Open Education as a different approach to professional learning. Professional learning through Open Education (PLOE) is the phenomenon to be explored in this study.

2.5. Open Education and Teachers' Professional Learning

In this study Open Education is interpreted as an alternative approach to professional learning that occurs within the digital context of the open Web. While acknowledging the pre-digital history of Open Education (Conrad & Prinsloo, 2020; Peters & Britez, 2008; Peter & Deimann, 2013), scholarship in this area does not fall within the scope of the literature review. This section begins with a brief review of the history and technologies of the open Web, followed by a discussion of how Open Education is conceptualised in the literature. Finally, this discussion of the open Web, and Open Education, is applied to the online professional learning of K-12 teachers. This section concludes with a statement of the boundaries of the phenomenon explored in this study, namely professional learning through Open Education (PLOE).

2.5.1. The Open Web

In the early 1990s Sir Tim Berners-Lee created a system called the "Word Wide Web" while working at CERN, a physics research facility in Europe (Berners-Lee & Fischetti, 1999, p. 26). In the literature this system is referred to as the open Web, and/or the Web, both of which I will use interchangeably. Research conducted at CERN involved collaboration amongst a community of people from around the globe, across different cultures, time zones, and languages (Berners-Lee & Fischetti, 1999). To assist people with their work Berners-Lee designed the Web to function on top of the Internet "for a social effect" (Berners-Lee & Fischetti, 1999, p. 133). Instead of using specialist software for every activity, a Web browser was created for people to access the Web for a range of activities, for example, to communicate with each other via discussion forums, exchange emails and publish Web pages (Weller, 2020b). The technical and social infrastructure of the Web was also designed for everyone to use, and no-one to own and control (Weller, 2020b). This open and decentralised system democratised publishing and communication on the Internet (Weller, 2020b).

By the mid-2000s people from all walks of life engaged in social and creative practices on the open Web through the use of many free and interactive tools. For example, publishing content on blogs and wikis (Attwell, 2007; Brown & Adler, 2008); creating, uploading to, sharing and remixing "user generated content" like photographs and videos, on platforms such as Flickr and YouTube respectively (Hesmondhalgh, 2019, p. 12) and archiving and sharing references on social bookmarking platforms (Weller, 2020b). O'Reilly (2007) coined the term "Web 2.0" to reflect this new "architecture of participation" on the open Web (p. 17). In the context of education, the term "personal learning environment, or PLE" (Downes, 2017, p. 13) emerged as a way to conceptualise the spaces learners created on the open Web (Attwell, 2007). Individuals created their unique PLEs from the Web tools, platforms and resources they connected to, enabling them to take control of, and responsibility for, their own learning (Attwell, 2007; Couros & Hildebrandt, 2016). PLEs became a structure for informal, self-directed, learning on the open Web (Fournier et al., 2019; Martindale & Dowdy, 2016).

To incorporate the social aspect of learning into the structure of a PLE, the concept of a personal learning network (PLN) emerged (Couros & Hildebrandt, 2016). PLNs are defined as "the sum of all social capital and connections that result in the development and facilitation of a personal learning environment" (Couros & Hildebrandt, 2016, p. 154). The formation of networks for learning with other people is not a new concept, for example, it appeared in the workplace learning literature in the late 1990s (Digenti, 1999; Tobin, 1998). At that time there was a focus on collaborative learning in organisations, and workers were encouraged to develop a "personal learning network (PLN)" to build relationships for learning with others within, and external to, the workplace (Digenti, 1999, p. 53). In recent years, the concept of a PLN has been applied to research around K-12 teachers' professional learning (Krutka et al., 2017; Prestridge, 2019). This literature is reviewed in Section 2.5.3 below.

The previous paragraphs describe the open Web as a global, digital, networked context for learning that includes technology, web tools and platforms, content, and people. This context also fosters the social aspect of culture, defined for the purpose of this review as *"the dominant values and beliefs that influence decision-making"* (Bates, 2019, p. 518). Democratic values, such as equality, were embedded in the design of the early Web. Everyone could use it, and no-one had the right to own and control it. A culture of sharing

was emphasised, where users of the Web were able to freely contribute and distribute the content they created "with few restrictions or costs" (Brown & Adler, 2008, p. 18). A new culture of learning emerged (Inglis & Ehlers, 2009). Learner autonomy was valued, and learning was seen as "more bottom-up or democratic" (Downes, 2017, p. 4). Interactive tools and platforms were said to facilitate a "participatory culture" (Jenkins et al., 2006, p. 3; Jenkins et al., 2016). This culture referred to youth engaging in creative and expressive practices with digital media, and social practices that valued diversity and democracy (Jenkins et al., 2016). Ideally, every citizen had a voice, and every voice was heard (Jenkins et al., 2016). Participatory culture shared values with a broader network culture, such as openness and transparency (Jenkins et al., 2016). The "cultures of openness" described in the Open Education literature (Atenas et al., 2020, p. 22) embrace the values and beliefs mentioned in this paragraph, however, this optimistic culture of the open Web has implications (Siemens et al., 2020).

Information shared on the Web may be harmful, false and/or inaccurate (misinformation), sometimes deliberately so (disinformation) (Jenkins et al., 2016; Weller, 2020b; Siemens et al., 2020). People experience offensive behaviour, such as public shaming, trolling, harassment, and hate speech (Jenkins et al., 2016; Weller, 2020b). There are corporations who advertise and profit from user participation; concerns related to data ownership and use; and privacy, copyright and censorship issues (Hesmondhalgh, 2019; Jenkins et al., 2016; Weller, 2020b). It appears that the open Web is a "complex digital landscape" (Siemens et al., 2020, p. 112). This study seeks to understand learning in this context, within which people, abundant resources, and digital tools are connected in networks.

Connectivism, a term introduced in 2004, is a theoretical framework used to conceptualise knowledge and learning in digital networks (Downes, 2020; Kop & Hill, 2008; Siemens et al., 2020). Connectivists refer to networks as "connections between entities" (Siemens, 2005, p. 5). Entities like people, websites, databases, repositories of resources, and learning communities are seen as "nodes" in a network (Downes, 2012, p. 56). Through the connectivist lens, learning is the process of forming, exploring, and adjusting the connections between nodes (AlDahdouh et al., 2015; Downes, 2012, 2017; Siemens, 2005). This includes learners forming connections between the new knowledge that emerges from

their digital networks, and their backgrounds and previous experiences (Downes, 2012). A cyclical process is completed when learners share their learning back to people in their digital networks (Kop & Hill, 2008). This understanding of connectivist learning is often applied to learning through problem solving (Downes, 2020).

Solving problems often requires complex knowledge (Downes, 2020). From a connectivist perspective, the knowledge that is needed to address a problem will not be found in the pre-existing knowledge of one person, then transferred to learners in a network (Siemens, 2005; Siemens et al., 2020). Rather, connectivists assume that knowledge is "distributed across a network of connections" (Downes, 2012, p. 9). Generally, "networked or connected learning or connective knowledge" means that learners connect existing knowledge found in different nodes in their networks (Siemens et al., 2020, p. 110). A core skill in this kind of learning is the "ability to see connections between fields, ideas, and concepts" (Siemens, 2005, p. 6), to recognise and interpret patterns that emerge from connections in a network (AlDahdouh et al., 2015; Downes, 2012).

Connectivist learning can be applied to an existing problem in the K-12 teaching community, that is, how to teach an integrated STEM curriculum. From a connectivist perspective, new knowledge about how to do this may emerge from the connection's teachers make in their networks. The coronavirus pandemic is a good example of an integrated STEM topic: it connects science "(e.g., viral infection)"; "technology (e.g., computer models)"; "engineering (e.g., designing masks)"; and "mathematics (e.g., exponential growth)" (Lee & Campbell, 2020, p. 941). On the Web there is abundant information in these areas for teachers to connect to (Lee & Campbell, 2020). For example, Our World in Data (n.d.) is a regularly updated, publicly available, Open Access database on the Web that provides information on the Coronavirus Pandemic (COVID-19). Teachers can connect to datasets on the Web, STEM professionals, fellow teachers, and so on, to make sense of phenomena like the pandemic. In doing so they may recognise, then interpret patterns that emerge from their connections, then use this new knowledge to plan lessons for their students.

Networks most likely to produce new knowledge have the characteristics of autonomy, diversity, openness and interactivity (Downes, 2012; Kop & Hill, 2008). Autonomy refers to learners managing their own connections and interactions in the network, and choosing what, and how, to learn (Downes, 2020). Diversity refers to learners interacting

with different people in terms of "gender, race, culture and socio-economic status" (Tschofen & Mackness, 2012, p. 134). It also means learners use a range of different tools and resources to learn (Downes, 2009, 2017). Openness is a feature of networks that enable anyone to enter and leave, whenever they want to, freely and easily (Downes, 2009, 2017; Tschofen & Mackness, 2012). There are "no boundaries" to how learners participate (Tschofen & Mackness, 2012, p. 137). For example, they communicate with each other, share resources and ideas, engage creatively, post occasionally, read, and lurk (Downes, 2009). For new knowledge to emerge, open networks depend on a "free flow of ideas and artifacts" (Tschofen, & Mackness, 2012, p. 136), otherwise the learning environment becomes more like an "echo chamber" (Downes, 2012, p. 97). Finally, interactivity refers to how knowledge in the network is produced. Knowledge is not centralised in one person then spread throughout the network, rather, knowledge emerges from the "interactions among people" (Downes, 2012, p. 99; 2017).

From a review of the literature above, the open Web as a digital context for learning is seen as a space/environment that consists of technology, interactive web tools and platforms, digital content, people, and the social aspect of culture. Connectivism is a theoretical lens used to conceptualise learning and knowledge in this complex environment. It is this technical and social infrastructure that enables "today's digitally-focused open education movement" (Havemann, 2020, p. 3). From a connectivist perspective, these principles can inform "pedagogies and educational strategies" (Downes, 2012, p. 438) for teachers' professional learning on the Web. The next section describes how Open Education (OE) is understood for the purpose of this study.

2.5.2. Open Education - Increasing Access to Education

Open Education (OE) refers to many things, such as the practices of teachers, the resources they use for teaching and learning, educational policies, values, and/or relationships between people (Cronin & MacLaren, 2018). In fact, Cronin and MacLaren (2018) ask the question "is open education a slogan or a philosophy, a metaphor, model, or movement?" (p. 127). Weller et al. (2018) view OE as an "evolving term that covers a range of philosophies and practices" (p. 109). Their recent exploration of the literature identified eight sub-categories of this concept, namely distance education, e-learning, Open Education in schools, Open Educational Resources (OER), Massive Open Online Courses (MOOCs), Open Access

publishing (OA), social media and Open Educational Practice (OEP). These sub-categories describe the different ways people increase their access to some form of education (Weller, 2020a).

The sub-categories mentioned above are not all relevant to this study, in the context of K-12 teachers of STEM subjects having increased access to education in the form of professional learning. Distance education is related to higher education, and e-learning to the delivery of education online (Weller et al., 2018). The Open Education in school's sub-category refers to the historical origins of K-12 education in the pre-digital era (Conrad & Prinsloo, 2020; Peter & Deimann, 2013). Massive Open Online Courses (MOOCs) are an option for teachers' professional learning; however, they are not reviewed in isolation to the remaining sub-categories relevant to this study, namely Open Educational Resources (OER) (including Open Access publishing), social media and Open Educational Practice (OEP). Since social media facilitates aspects of OER and OEP, it is included in the review of the literature related to these two sub-categories. In the next section I discuss the main features of OER and OEP in the context of Open Education and the professional learning of teachers.

Open Education as Open Educational Resources. This interpretation of Open Education focuses on educational content, referred to as Open Educational Resources (OER) (Havemann, 2020). Hence, the word 'open' in Open Educational Resources (OER) refers to "what something *is*" (Tur et al., 2020, p. 4). The United Nations Educational, Scientific and Cultural Organization define OER as:

> …learning, teaching and research materials in any format and medium that reside in the public domain or are under copyright that have been released under an open license, that permit no-cost access, re-use, re-purpose, adaptation and redistribution by others (UNESCO, 2019, p. 5)

The most 'open' kind of OER is one that is no longer protected by copyright law (expired copyright), has moved into the public domain, and is generally free of restrictions for anyone to access and use. For a resource still protected under copyright, the owner/creator may grant other people the permission to access and use it in certain ways (re-use, re-purpose, adapt and redistribute at no cost). This is the purpose of an open license, and the most frequently used license for educational content is the "Creative Commons" license (CC) (Downes, 2017, p. 7). Some CC licenses place restrictions on how a resource can be used, making it less 'open'.

The practices related to how OER can be used are discussed in the section below on Open Educational Practices (OEP).

There are many different types of OER (for example: curriculum documents, podcasts, data sets, instructional videos, blog posts, open textbooks, and Open Access journals) that come in different formats (for example: simulations, audio, video, images and text). For example, open textbooks are a specific type of OER that teachers and learners can use as an alternative to expensive proprietary textbooks (Pitt et al., 2020). This makes education more "affordable, flexible, and accessible" (Weller, 2020b, p. 141). Open Data is another type of OER that refers to datasets on the Web (Atenas et al., 2015). For example, the Commonwealth Scientific and Industrial Research Organisation (CSIRO, n.d.-b) support teachers and students by providing Educational Datasets that can be linked to the Australian Curriculum: https://www.csiro.au/en/Education/Programs/Datasets. Finally, Open Access (OA) journals are a type of OER that provide teachers with an alternative to school-based subscriptions. They are a convenient way for teachers to easily access, read and apply contemporary educational research to their practice (Blomgren & McPherson, 2018). For example, the International Journal of STEM Education (SpringerOpen, n.d.) is a peer reviewed journal that promotes original research from around the globe in the field of STEM education. Despite the abundance, diversity and benefits of OER available on the Web, people across different education sectors (including K-12), range from being aware of OER and open licenses, to having some awareness of either one or the other, to having limited awareness of both (Weller et al., 2016; Weller, 2020b).

In this section OE is interpreted as "what something *is*", namely, OER (Tur et al., 2020, p. 4). The Cape Town Open Education Declaration (2007) offers a broader interpretation:

> …open education is not limited to just open educational resources. It also draws upon open technologies that facilitate collaborative, flexible learning and the open sharing of teaching practices that empower educators to benefit from the best ideas of their colleagues. (Cape Town Open Education Declaration, 2007, para. 4)

In the next section OE is seen in this broader context of practice, in other words, as "something someone *does*" (Tur et al., 2020, p.4).

Open Education as Open Educational Practices. One way to understand Open Educational Practices (OEP) is in terms of what a user 'does' with OER, in other words, the "creation and use" of OER (Cronin & MacLaren, 2018, p. 128). As mentioned in the previous section, when an OER is released under an open licence, users are permitted to access, re-use, re-purpose, adapt and redistribute it, at no cost (UNESCO, 2019). These permissions are often rephrased as retain, reuse, revise, remix and redistribute, namely, the "5R permissions that are characteristic of OER" (Wiley & Hilton, 2018, p. 133). They give OER users the right to engage in a range of practices that are summarised in Table 2.2.

Table 2.2

The 5R Permissions and Practices of OER

5R Permissions Users have the right to…	**Practices users may engage in** (Wiley & Hilton, 2018, p. 134, 135)
Retain	Make, own, and control copies of the content (e.g., download, duplicate, store, and manage)
Reuse	Use the content in a wide range of ways (e.g., in a class, in a study group, on a website, in a video)
Revise	Adapt, adjust, modify, or alter the content itself (e.g., translate the content into another language)
Remix	Combine the original or revised content with other material to create something new (e.g., incorporate the content into a mashup)
Redistribute	Share copies of the original content, your revisions, or your remixes with others (e.g., give a copy of the content to a friend)

Users can engage in all of these practices with a public domain resource. However, depending on the Creative Commons license chosen by its creator/owner, users of a copyright protected resource may be restricted in what they can legally 'do' (Wiley & Hilton, 2018). For example, the least 'open' (most restrictive) CC license allows people to retain and reuse, but not revise or remix, an OER. The unchanged resource can be redistributed (shared), but not used for commercial purposes (Creative Commons, n.d.).

Another way to understand Open Education as OEP is more "expansive" than just focusing on what users do with OER (Cronin & MacLaren, 2018, p. 128). Bali et al. (2020) suggest that a broader understanding of OEP covers many types of openness, that may or may

not include OER. For example, openness may refer to values and attitudes (Pitt et al., 2020), managing one's online identity (Weller, 2020b), and collaboration in networks (Cronin & MacLaren, 2018). Much of the research conducted on the recent concept of OEP occurs in the higher education sector. Nevertheless, there is evidence that K-12 teachers find and customise OER to meet the diverse needs of their students (de los Arcos et al., 2016). For example, a study conducted by Mason and Kimmons (2018) showed that teachers prefer open science textbooks to their regular textbooks, because they can be customised for relevance, accuracy, and alignment to the curriculum. K-12 teachers also reflect on their practice when they are exposed to different pedagogies through their use of OER (de los Arcos et al., 2014). Since research around K-12 teachers' OEP is limited, this review turns to the larger body of literature on K-12 teachers' online professional learning for signs of openness in their practice.

2.5.3. Teachers' Online Professional Learning

In the context of this study OEP refers to what teachers 'do' to learn on the Web, including their practices related to OER. In the literature related to K-12 teachers' online professional learning, via social media and personal learning networks (PLNs), there is seldom reference to educational content/resources as OER, and the term OEP is rarely used. In the following review of this literature, the term educational content/resources is interchanged with OER, and teachers' activities are interchanged with OEP.

As discussed in Section 2.5.1 the Web as a context for professional learning includes a social infrastructure, of which social media is a part (Weller, 2020b). Facebook and Twitter are examples of social media commonly used by teachers to facilitate their professional learning (Bobis et al., 2020; Carpenter et al., 2020b; Lantz-Andersson et al., 2018; Prestridge, 2019). Social media enables flexible professional learning for teachers who need to overcome the constraints of cost, time, distance and isolation (Powell & Bodur, 2016; Prestridge, 2019). They can learn anytime, from anywhere, according to their needs and circumstances (Greenhalgh & Koehler, 2017; Lantz-Andersson et al., 2018; Prestridge, 2019). For example, teachers from around the globe use Twitter to share knowledge and ideas about their experiences of teaching (Lantz-Andersson et al., 2018), and share content in the form of resources (Carpenter et al., 2020a). Specific hashtags enable teachers to focus their sharing, conversations and other activities around topics of interest (Couros & Hildebrandt, 2016). For

example, during the current Covid-19 pandemic (World Health Organization, n.d.), the hashtags #remoteteaching and #remotelearning provided a "treasure trove of resources, ideas, and insights" to support teachers through their transition to remote teaching (Carpenter et al., 2020a, p. 156). In addition to using Twitter hashtags, it is now common practice for teachers to form networks and communities on the Web (Lantz-Andersson et al., 2018).

A particular type of network described in the literature on K-12 teachers' professional learning is a Personal Learning Network (PLN). Trust et al. (2016) define PLNs as "uniquely personalized, complex systems of interactions consisting of people, resources, and digital tools that support ongoing learning and professional growth" (p. 28). They include formal and informal learning activities, in face-to-face and online environments (Krutka & Carpenter, 2017; Trust & Prestridge, 2021). PLNs are seen as a place to collaborate with colleagues online (Prestridge et al., 2019), where opportunities for learning are ongoing and immediate (Prestridge, 2019). Within their PLNs, teachers participate in professional learning on social media in different ways (Prestridge, 2019). Some use their PLNs to "consume" content/resources, and follow others for what they share (Prestridge, 2019, p. 16). Other teachers are more active in how they participate. They engage in "reflective cycles" of consuming and creating content/resources, experimenting with new ideas in the workplace, and feeding new knowledge back into their PLNs (Prestridge, 2019, p. 18). Thus, in this literature, there are signs of openness in the online practices of teachers.

There is recognition of teachers' increased access to abundant resources through their PLNs (Prestridge, 2019), and the availability of resource repositories for teachers to connect to (Oddone et al., 2019; Prestridge et al., 2019. There is also mention of sharing, consuming, generating (Prestridge, 2019), and remixing (Oddone et al., 2019) content/resources. However, there is little awareness of content/resources as OER, open licenses, or practices associated with the creation and use of OER in this body of literature. This is consistent with the findings of Weller et al. (2016) that people across different education sectors (including K-12), may only have some, or limited awareness of OER and open licenses. Additionally, the term participatory culture is widely used but there is little discussion of the values underpinning this shared culture and practice, or the broader culture of learning on the Web.

This literature does, however, raise awareness of the challenge's teachers face when creating and maintaining their PLNs in digital environments (Krutka et al., 2017). For

example, being harassed and trolled on social media (Carpenter et al., 2020b), feeling insecure, and negotiating their personal and professional identities (Carpenter et al., 2020b; Lantz-Andersson et al., 2018). Teachers may also be challenged by the fast, instant, and superficial sharing of others in their network (Lantz-Andersson et al., 2018). Despite these challenges, the Web has become an important place where teachers participate in meaningful professional learning activities, reflect on, and develop their practice, support each other, and become more confident and motivated practitioners (Lantz-Andersson et al., 2018; Macià & García, 2016). From the perspective of teachers themselves, their PLN experiences have "affective, social, cognitive, and identity benefits" (Trust et al., 2016, p. 31). The usefulness and value of different sharing and learning practices, and the impact they have on the classroom practices of teachers, are areas recommended for future research (Lantz-Andersson et al., 2018; Prestridge et al., 2019).

2.5.4. Boundaries of the Phenomenon of PLOE

This study explores the different ways in which Australian K-12 Teachers of STEM subject areas experience Professional Learning through Open Education (PLOE). The phenomenon of PLOE is bounded by the concepts of professional learning, the open Web, and Open Education. These concepts are summarised as:

- Professional learning: learning that results from any experience through which teachers themselves perceive they have learned something related to their roles as K-12 teachers involved in STEM education.
- The open Web: the digital context for teachers' professional learning that includes Web tools, platforms, resources, people, and culture.
- Open Education: the Open Educational Practices (OEP) of teachers using the open Web as a context for professional learning.

In the following section of the chapter, knowledge gaps identified in the literature informing this study are highlighted, and implications for the study are briefly discussed.

2.6. Highlighting the Knowledge Gaps and Where my Study Fits

The literature related to the contemporary context of Australian teachers' work revealed a need for professional learning to be more applicable to the changes and challenges teachers face in the workplace. It also revealed that there is no consistent understanding of, or approach to, STEM education to guide teacher practice in the classroom, and that educational research in this area is lacking (Blikstein et al., 2017). More information is needed regarding how teachers can be supported as they adapt to teaching a more contemporary and integrated STEM curriculum (Timms et al., 2018). My study can make a contribution because I seek to explore and understand, if a self-directed, bottom up, approach to professional learning that occurs in open, digital networks can support teachers as they learn about STEM education.

In the context of the knowledge acquisition metaphor, the literature on the effective professional learning of K-12 teachers was reviewed. Seven evidence-based, design elements of effective professional learning emerged (Darling-Hammond et al., 2017). Empirical research shows that many professional learning approaches with these recommended design elements are ineffective in facilitating change in teachers' knowledge, practice, and/or student learning (Desimone & Garet, 2015; Darling-Hammond et al., 2017; Hammond & Moore, 2018; Kennedy, 2016; Opfer, 2016; Kraft et al., 2018). Researchers conclude these design elements are "necessary but not sufficient to effect change" (Borko, 2019; Osborne et al., 2019, p. 1069). My study seeks to explore a much needed alternative approach to professional learning that may effect change.

It is suggested that the generic nature of professional learning activities may ignore factors that have an impact on effectiveness, such as the experiences of individual teachers and the context of schools within which their work is situated (Beswick et al., 2016). It is the former factor that my study targets, specifically experiences of teachers from their own perspective. Experience is a central concept in the literature on the transformative theory of adult learning (Taylor & Cranton, 2013). Scholars in this field recommend further exploration of this concept, particularly the nature and meaning of experience, how to describe experience and distinguish between different kinds of experiences (Taylor & Cranton, 2013). My interest lies in the meaning teachers ascribe to their different experiences of PLOE in contrast to whether it is an effective, alternative approach to professional learning for teachers of STEM subject areas. Therefore, my study fits in this recommended area of research.

Social media platforms enable teachers to access and share content in the form of Open Educational Resources (OER). However, the literature related to how K-12 teachers perceive and use OER is limited (de los Arcos et al., 2016). In fact there is limited research around K-12 OER (Blomgren & McPherson, 2018), and the use of Open Educational Practices overall (OEP) (Cronin, 2017). This study can contribute to this body of literature. In the K-12 teachers' professional learning literature, research shows that teachers already manage and self-direct their professional learning in online environments (Bobis et al., 2020; Kelly, 2019; Prestridge, 2019); experience flexible learning, anytime, from anywhere, according to their needs and circumstances (Greenhalgh & Koehler, 2017; Lantz-Andersson et al., 2018; Prestridge, 2019); and have found ways to overcome the constraints of cost, time, distance and isolation (Powell & Bodur, 2016; Prestridge, 2019). The popular and accepted practice of teachers learning in digital networks is well known, however, little is known about what kind of learning occurs in these networks (Kelly, 2019; Lantz-Andersson et al., 2018; Prestridge & Main, 2018). The nature and worthiness of K-12 teachers' collaborative practices in digital networks is a recommended area for further research (Bobis et al., 2020; Lantz-Andersson et al., 2018). Trust and Prestridge (2021) assert that research around Professional Learning Networks (PLNs) lacks complexity, and that further studies are needed about "how and why learning happens within a multifaceted network of people, spaces, and tools" (p. 4).

I propose to conduct this study from the perspective of teachers themselves. This will be done by undertaking an interpretive study on the experiences of a group of Australian teachers of STEM subject areas who use the Web to learn about STEM education. I particularly want to understand the nature of the different experiences' teachers have of this phenomenon, therefore phenomenography will be used as the theoretical and methodological framework underpinning my research design.

2.7. Chapter Summary

In this chapter I reviewed the scholarly literature related to the context of Australian teachers and their workplaces, including STEM education; teachers' professional learning; the common metaphors used to conceptualise learning and professional learning; the Open Web as a context for professional learning; Open Education as OER and OEP; and teacher's online professional learning. The boundaries of the phenomenon of PLOE were also defined. This review builds upon the limited literature around Open Education related to the professional learning of K-12 teachers. In doing so I have identified a number of areas this study can make a contribution towards, such as knowing how teachers can be supported as they adapt to teaching a more contemporary and integrated STEM curriculum; finding a much needed alternative approach to professional learning that may effect change in the knowledge and practice of teachers; understanding the professional learning experiences of teachers from their perspective; knowing more about teachers' perceptions and use of Open Educational Resources, and whether the interactive practices of teachers on the Web are useful, valued and have an impact on their daily practices in the classroom. In the next chapter I will describe the theoretical and methodological framework underpinning this research. It consolidates my research questions, philosophy, methodology, methods, and trustworthiness issues, into a coherent research design.

CHAPTER 3. RESEARCH DESIGN

> Because a design always exists, it is important to make it explicit, to get it out in the open where its strengths, limitations, and consequences can be clearly understood. (Maxwell, 2013, p. 3).

In the last chapter, I reviewed the relevant research in the three main areas of scholarship that inform my study: the context of Australian K-12 teachers involved in STEM education, professional learning, and Open Education. The knowledge gap that is addressed by this study was identified and elaborated. This is the first of two chapters that collectively describe and justify how my research was conducted, from my underpinning philosophical assumptions through to the specific methods by which data were collected and analysed. This chapter articulates the theoretical and methodological framework underpinning this study, namely phenomenography. Within this framework, my research questions, philosophy, theory, and methodology are presented and justified, along with considerations related to research rigour and quality.

For the purpose of clarity, I begin with a definition of the key terms key terms used to describe a research design and methodology and indicate how they are used in this study. Next, I explain my philosophical orientation (ontological and epistemological perspectives) and the world view, or paradigm, that informs this orientation. I then situate this study in the interpretive paradigm and describe and justify my choice of phenomenography as the qualitative methodology best suited to the nature of the research problem and questions. This is followed by a description of the characteristic theoretical and methodological features of phenomenography that inform the research design. The research design is presented followed by a discussion of how issues of trustworthiness are addressed.

3.1. Key Terms Used in the Research Design

Upon entering the world of research methodologies as a new researcher, I confronted a bewildering array of terms. It became apparent that many of these have flexible meanings, particularly in an emergent field such as phenomenography. Indeed, since its origins, phenomenography has been referred to as many things, including a research method (Gibbings et al., 2015; Marton, 1981), a research approach (Akerlind, 2017; Marton &

Booth, 1997; Richardson, 1999; Yates et al., 2012), a research specialisation (Marton, 2015; Pang, 2003), a research orientation (Svensson, 2016), a research methodology (Ashworth & Lucas, 2000; Booth & Ingerman, 2015; Laurillard, 2012; Reed, 2006), an empirical research paradigm (Pang & Ki, 2016), and as belonging to a research tradition (Pang & Ki, 2016; Rovio-Johansson & Ingerman, 2016; Svensson, 2016). Finally, phenomenography is referred to as having "elements of both method and theory" (Collier-Reed & Ingerman, 2013, p.4), and as being a research design in its own right (Tight, 2016).

Such a plethora of terms constituted a problem for me, the novice researcher, and for my mentors. My thesis aims to present a clear and coherent argument based on evidence gathered during a research study conducted with methodological rigour, but this is difficult to achieve when terminology may have such variant meanings. In the interests of clarity, Table 3.1 below presents my definitions of relevant methodology related terms, with an indication of how they are used in this study. These terms are elaborated in different sections of this chapter.

Table 3.1

My Definitions of Key Terms as Used in this Thesis

Term	My definition	As used in this study
Ontology and epistemology	The philosophical beliefs and assumptions about what can be known and the nature of the world.	A non-dualistic relational view of the reality of experience underpins this phenomenographic study.
Paradigm	The worldview which guides and shapes research.	An interpretive paradigm is suited to this study of the phenomenon of teachers' experiences of professional learning through Open Education.
Research approach	The plans and procedures that align a worldview to the specific steps that will be adopted to suit the nature of the research question.	A qualitative approach is best suited to exploring and finding patterns in how teachers experience professional learning through Open Education.
Methodology	The theory and processes that underpin why particular methods are chosen and used, and how these are linked to the outcomes of a study.	Phenomenography is an interpretive, qualitative methodology best suited to explore variation of experience. The anatomy of awareness is a theoretical framework through which data are analysed to conceptualise variation of experience.
Research design	An overall strategy that brings together the different components of a study, in a logical and unified way, to address the research problem.	This research design integrates the different components of an interpretive, qualitative study. It is based on methodological and theoretical characteristics of phenomenography. A diagram is used to represent the different components, including where the methods of data collection and analysis are placed within the overall strategy.
Methods	The specific procedures followed, including an outline of the data collection and analysis techniques and tools	As outlined in Chapter 4, the techniques and tools used to collect qualitative data from participating teachers of STEM subjects included announcements via social media, an expression of interest form, an online survey and a semi-structured interview.

Note that the selection of each term for my study is based on the decision made above it in the hierarchy. The derivation and justification from the literature for the choice and working definitions of these terms will be presented in detail throughout this chapter in the order in which they appear in Table 3.1, beginning with my philosophical orientation (ontological and epistemological perspectives).

3.2. Ontology and Epistemology

As explained in Chapter 1 and further developed through the literature in Chapter 2, the research problem is that, for many teachers, professional learning lacks effectiveness and meaning, is fragmented, disconnected, and can be irrelevant to the realities of classroom practice (Cole, 2012; Lieberman & Pointer Mace, 2010; Opfer & Pedder, 2011; Webster-Wright, 2009). Therefore, I chose to explore, from the perspective of teachers, their experiences of a contemporary approach to professional learning: Open Education. In the first instance, my decisions regarding how to approach this study were underpinned by specific philosophical beliefs and assumptions, many of which I was not initially aware. Jackson (2013) points out the importance of being open and transparent about these beliefs and assumptions, both in terms of how they shape the design of the research and for this design to be regarded as credible and rigorous. Thus, began my search for my philosophical beliefs and assumptions and my entry into the studies of ontology and epistemology.

According to Willis (2007) ontology "is concerned with the nature of reality (or being or existence), and various ontological positions reflect different prescriptions of what can be real and what cannot" (p. 9). To understand the phenomenon of professional learning through Open Education through the experience of teachers, I was guided by specific beliefs about the nature of reality. In this study, the nature of reality refers to experience, and my beliefs about experience form my ontological assumptions. Therefore, I needed to explore and understand the nature of an experience in order to articulate my ontological perspective. In the literature, I initially encountered dualistic ontologies; that is, that an experience could be considered as an aspect of external reality separated from our interpretation of it, or, as a cognitive construct in the minds of humans (Akerlind, 2015; Bowden, 2005; Marton & Booth, 1997).

Marton (2000) however, claims a non-dualistic ontological position:

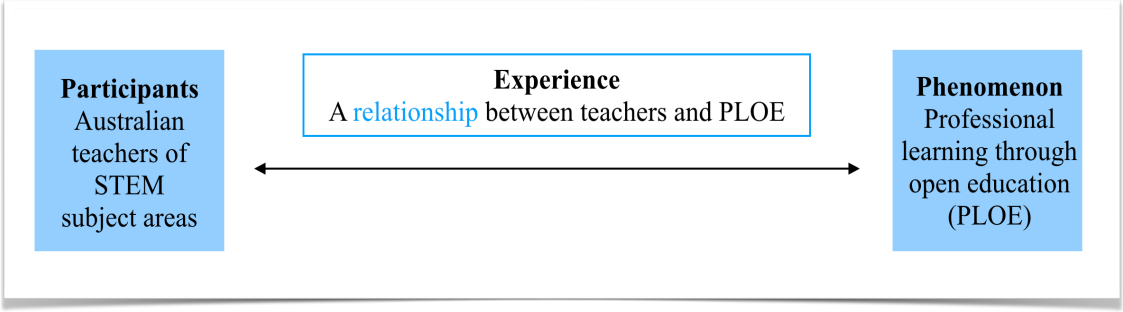
> There are not two worlds: a real, objective world, on the one hand, and a subjective world of mental representations, on the other. There is only one world, a really existing world, which is experienced and understood in different ways by human beings. It is simultaneously objective and subjective. (Marton, 2000, p. 105).

This was challenging to me, as this conflicted with my scientific, realist view of an external, objective world.

Further consideration of the writings of Marton (Marton & Booth, 1997; Marton, 2000) and Bowden (2000b) brought me to an understanding that researchers could hold a non-dualistic relational view of experience. As represented by Figure 3.1, this ontological position now underpins the nature of experience as understood in this study.

Figure 3.1

A Representation of the Relational Ontological Position Underpinning this Research Design



This non-dualistic ontology includes both teachers and the phenomenon of PLOE in relation to one another. My next consideration as the researcher holding this relational ontological position are my epistemological beliefs and assumptions.

Epistemology, according to Willis (2007) "is concerned with what we can know about reality (however that is defined) and how we can know it" (p. 9). My non-dualistic ontological view of experience (reality) means the knowledge I seek – that is knowledge of how teachers experience professional learning through Open Education – emerges from an understanding of the relationship between teachers and PLOE. I assume knowledge is created through teachers thinking about their external reality, and that it can be accessed through language (Svensson, 1994). I also assume knowledge will vary depending on the different

perspectives of teachers and the context within which they work (Svensson, 1994). In the literature these "experiential relations" (Marton, 1992, p. 253) are referred to as conceptions (Collier-Reed & Ingerman, 2013; Dahlin, 1994; Marton & Pong, 2005), that have the "character of knowledge", the truth of which is not certain (Svensson, 1994, p. 16). In the literature, conceptions are also referred to interchangeably with the terms "ways of experiencing" and "ways of understanding" (Marton & Pong, 2005, p. 336). The term "way of experiencing" is used throughout this thesis when referring to the relation between the experiencing subject – the teachers – and the experienced phenomenon, professional learning through Open Education.

3.3. Paradigm

With a background in scientific research and teaching in STEM subject areas, my worldview was shaped by the scientific paradigm. I researched aspects of the physical, material world and gained knowledge of this world by conducting experiments according to the scientific method. I believed my external, objective world was independent of my inner, subjective world, making my role in the research process detached and impartial (Yilmaz, 2013). As a secondary school science teacher, I continued to hold this worldview while teaching the concepts of science and the methods of scientific experiments. At the time I was unaware of alternatives to the scientific, commonly referred to as the positivist, paradigm (Taylor & Medina, 2013). This changed towards the end of my teaching career and when my role changed from teacher to education researcher.

It was always my intention to explore the phenomenon of professional learning through Open Education. However, my interest was to understand how Australian teachers of STEM subjects experience this phenomenon, not to focus on the phenomenon itself. In other words, I wanted to understand professional learning through Open Education "in terms of the people that make up the world", not to look "for causality or laws that govern behaviour" (Reed, 2006, p.1). Therefore, I am not testing a theory or hypothesis by conducting experiments on a large group of teachers for the purpose of making generalisations (Willis, 2007). Instead, I am seeking to understand the different experiences of a small group of teachers, from their perspective, in the specific context of their professional learning through Open Education. The particular context within which this study is situated is K-12 Australian STEM education; specifically, Australian K-12 teachers of

STEM subject areas who are learning about STEM education on the Web. Since understanding the nature of this experience is an interpretive activity (Cohen et al., 2007), my worldview shifted to the interpretive paradigm.

Interpretive researchers seek understanding of people's experience of phenomena in specific contexts (Schwartz-Shea & Yanow, 2012), and understanding is seen as knowledge in the interpretive paradigm (Willis, 2007). What I did not realise previously was that interpretive researchers do not prioritise the type of data they collect, in fact, one can interpret meaning from quantitative and/or qualitative data (Schwartz-Shea & Yanow, 2012; Willis, 2007). However, describing the perspectives of teachers, in terms of what PLOE means to them, is research of a qualitative nature (Daher et al., 2017; Patton, 2015). Thus, the philosophical views of interpretivism guide and shape this research as a qualitative study.

3.4. Research Approach

Qualitative research is suited to exploration of people's lived experiences of a new phenomenon such as PLOE, in specific contexts (Marshall & Rossman, 2016; Patton, 2015). It requires the researcher to have an open mind, "to expect the unexpected, look for it, and see where it leads you" (Patton, 2015, p. 10). In keeping with this characteristic of interpretive, qualitative research, my intention was to be open minded to the different ways teachers experienced PLOE, otherwise the opportunity would be missed to uncover new and surprising aspects of their experiences (Limberg, 2008). As an interpretive researcher I need to be open to this possibility (Schwartz-Shea & Yanow, 2012). Additionally, qualitative researchers acknowledge that what they bring to their research, such as their background and experience, matters (Patton, 2015; Schwartz-Shea & Yanow, 2012). As I explained in the previous section, the focus of this inquiry is shaped by my background and experience in teaching, professional learning and learning on the Web. It is also shaped by my knowledge of relevant theoretical concepts from the literature. I acknowledge that my influence is an inherent part of this research approach and explicitly address this issue throughout the thesis.

A qualitative approach is best suited to exploring how teachers experience professional learning through Open Education. However, qualitative research covers a diverse "group of methodologies with different theoretical underpinnings and different ways of thinking about knowledge (Kuper et al., 2008, p. 404). Several of these methodologies are

compared in the next section, as are the methodological implications of taking a qualitative research approach.

3.5. Methodology

According to Crotty (1998), methodology is "the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes" (p. 3). The methodology I have chosen is informed by the interpretivist assumptions discussed in the previous sections. However, there are a range of methodologies within the interpretive paradigm, such as grounded theory, ethnography, phenomenology, and phenomenography (Patton, 2015; Willis, 2007; Yilmaz, 2013). To select phenomenography for this study I needed to consider the differences between these methodologies.

Ethnography is the study of cultures, where culture refers to how members of a community behave and what they believe (Marshall & Rossman, 2016; Patton, 2015; Richardson, 1999). Based on the assumption that, over time, people in groups will interact and develop a culture (Patton, 2015), ethnographers attempt to find out how this culture is formed and maintained (Marshall & Rossman, 2016). They immerse themselves in the culture they are interested in studying and, although a variety of methods can be used to collect data, their main approach is to observe participants (Marshall & Rossman, 2016; Patton, 2015). Their findings, in the form of written descriptions (Richardson, 1999), are interpreted and applied from a cultural point of view (Patton, 2015). Grounded theory, on the other hand, is the study of social processes and interactions (Denzin & Lincoln, 2011). The purpose of grounded theory is to build theories that explain these processes and interactions (Marshall & Rossman, 2016; Silverman, 2011). Theoretical sampling occurs, which is not based on the demographic characteristics of the participant population, but on the properties of a tentative category (Silverman, 2011). Qualitative data are collected, a tentative theory is developed, then more data are collected to test the theory (Willis, 2007). The processes of data collection and data analysis occur simultaneously (Denzin, & Lincoln, 2011; Marshall, & Rossman, 2016; Patton, 2015), and are inductive, comparative and iterative (Patton, 2015). Grounded theorists search for explanations for what caused certain events and interactions (Marshall & Rossman, 2016), while staying close to, or 'grounded' in the real world (Patton, 2015).

Phenomenology and phenomenography are methodologies that researchers use to interpret the meaning of experience of a phenomenon, from the perspective of someone undergoing the experience. The common aim of phenomenology and phenomenography is to "reveal human experience and awareness as an object of research" (Barnard et al., 1999, p. 213; Marton & Booth, 1997). However, there are differences between these methodologies (Marton, 1986; Svensson, 1997; Uljens, 1996). Firstly, phenomenology originates in philosophical thought (Giorgi, 2006; Patton, 2015), whereas phenomenography developed within a learning and teaching context (Larsson & Holmström, 2007). In other words, phenomenography has pedagogical origins (Barnard et al., 1999), emerging as an alternative to the traditional positivist and quantitative educational research traditions (Svensson, 1997). Regardless of their origins, both methodologies enable researchers to describe the lived experiences of a phenomenon from the perspective of those experiencing a phenomenon (Marton & Booth, 1997).

The second main difference between phenomenography and phenomenology is "the study of human beings' ways of experiencing phenomena in the world is different from the study of the world as it really is." (Limberg, 2000, p. 54). In phenomenology the researcher takes a first-order perspective, where the world is described as it is, whereas phenomenographers take a second-order perspective, where the world is described as it is experienced (Barnard et al., 1999). Phenomenography's second order perspective refers to the researcher's intention to understand the subject's experience of the phenomenon (that is, understanding other people's understandings) (Marton & Booth, 1997). Thirdly, in phenomenography there is a focus on the essence (invariant aspects) of individual experience of a phenomenon in phenomenology, whereas it is variation of collective experience across a group of people that is emphasised in phenomenography (Barnard et al., 1999; Eddles-Hirsch, 2015; Larsson & Holmström, 2007; Stenfors-Hayes et al., 2013; Marton & Booth, 1997). Finally, with respect to findings, the researcher's descriptions of phenomena are rich and full in phenomenology (Eddles-Hirsch, 2015), but not in phenomenograpgy. Marton and Booth (1997) refer to researcher's descriptions as "stripped" but retaining the "structure and essential meaning" of the different ways a phenomenon is experienced (Marton & Booth, 1997, p. 112). Data analysis reveals meaning units in phenomenology compared to categories of description and an outcome space following phenomenographic analysis (Barnard et al.,

1999). A summary of the differences between phenomenology and phenomenography is given in the Table 3.2 below.

Table 3.2

Comparing Phenomenology and Phenomenography as Research Methodologies

	Phenomenology	**Phenomenography**
Origins	Philosophical (Giorgi, 2006; Marshall & Rossman, 2016).	Empirical, educational research (Marton, 1981; Svensson, 1994)
Emphasis	Individual experience (Barnard et al., 1999)	Collective experience (Barnard et al., 1999)
Object of research	The essence of experience (Larsson & Holmstrom, 2007; Patton, 2015); or "invariant structures" of the phenomenon experienced (Eddles-Hirsch, 2015, p. 258)	Variation of experience (Larsson & Holmstrom, 2007; Marton & Booth, 1997)
Data analysis	Identification of meaning units (Barnard et al., 1999)	Constitution of categories of description, and the structural relationships between them, into an outcome space (Akerlind, 2005e)
Researcher perspective	First-order: the world is described as it is (Barnard et al., 1999)	Second-order: the world is described as it is experienced (Barnard et al., 1999; Marton & Booth, 1997)
Researcher descriptions	Rich, detailed (Eddles-Hirsch, 2015)	"stripped description" that retains "structure and essential meaning" (Marton & Booth, 1997, p. 112)

I am not studying the culture of a group of teachers using the Web to learn about STEM education, although culture may be an aspect of how the phenomenon of PLOE is experienced. Therefore, ethnography is not the most appropriate choice. Unlike grounded theory, I am not generating a theory to explain the cause of social processes and interactions when teachers engage in PLOE, although I am interested in describing and understanding the

different ways these processes and interactions are experienced. Even though human experience is the focus of phenomenology and phenomenography, it is the phenomenographic focus on variation of experience, rather the focus on essence of experience made by phenomenologists, that made a difference to which methodology was chosen. The former met the purpose of this study and, on this basis, was considered the more appropriate methodology to adopt. The implications of the choice of phenomenography for the study are now discussed.

3.6. Characteristics and Features of Phenomenography as a Distinctive Methodology

In the early 1970s, educational researchers at the University of Gothenburg became interested in changing their approach to studying student learning (Svensson, 1997). In response to objectivist views of knowledge dominating educational and psychological research at the time, researchers changed from assessing student knowledge through quantitative measures, such as testing, to describing student knowledge in terms of understanding and meaning (Svensson, 1997). It was uncommon for researchers to investigate learning as experienced by students (Pramling Samuelsson & Pramling, 2016). Nevertheless, researchers were interested in describing what students understood instead of how much they were able to learn (Gibbs et al., 1982), or whether they were right or wrong (Svensson, 1997). Researchers were particularly interested in variation in meaning students expressed, not variation in the quantity of information they retained (Marton, 1986; Svensson, 1997).

It is from these interests that "phenomenography emerged as a distinctive educational research approach" (Akerlind, 2017, p. 1). Marton (1986) and his colleagues found the different ways people understood many other phenomena to be interesting, arguing "the mapping of the hidden world of human conception should be a specialisation in its own right" (p. 145). Moving beyond its original focus, phenomenographic research has extended into many areas (Bowden, 2000a; Rovio-Johansson & Ingerman, 2016), including engineering education (Dringenberg et al., 2015), medical and health care research (Stenfors-Hayes et al., 2013), library and information research (Yates et al., 2012), networked learning (Cutajar, 2017), inquiry teaching (Ireland et al., 2011), and adult education (Brookfield, 1994). In all of these studies the aim was to research variation in the way a particular phenomenon is experienced (Akerlind, 2005a). Similarly, I chose phenomenography to reveal

variation in the way the phenomenon of PLOE is experienced by Australian teachers of STEM subject areas.

Based on understanding its historical development "as a distinctive educational research approach" emerging in Sweden in the 1970's (Akerlind, 2017, p. 1), I can now further justify why I chose phenomenography as an appropriate methodology to underpin my research design. Phenomenography is a methodology that originated in a pedagogical context (Barnard et al., 1999), enabling me to build upon the knowledge base of research relevant to my professional background and this study. It is empirical research (Akerlind, 2008; Booth, & Ingerman, 2015; Laurillard, 2002; Stenfors-Hayes et al., 2013). Therefore, I hope to inform the development of professional learning experiences "from a research-informed standpoint rather than rely on anecdotal information" from teachers engaged in PLOE to learn about STEM education (Green & Bowden, 2009, p. 57). Phenomenography is seen by others as a rigorous way to conduct qualitative research (Tight, 2016) which is important since I want my findings to be trusted. It also enables me to describe variation in the lived experiences of PLOE from the perspective of teachers experiencing this phenomenon (Marton & Booth, 1997). This is important since much of the literature on professional learning reviewed in Chapter 2 does not include the different views of teachers, but focuses on aspects of professional learning that others, such as school administrators and educational consultants, consider important. It is this focus on variation of experience, particularly the meaning of experience, that I see as having a practical application to the professional learning of Australian teachers of STEM subject areas.

3.6.1. Developmental phenomenography

As stated in Section 1.2, the aim of the study is to find the different meanings Australian teachers of STEM subjects attribute to their experiences of PLOE, with the objective of informing the development and delivery of meaningful professional learning to teachers who work in a similar context to those who participated in this research. This describes what Bowden (2000b) refers to as "developmental phenomenography" (p. 3), which "seeks to find out how people experience some aspect of their world, and then to enable them or others to change the way their world operates" (Bowden, 2000b, p. 3). The term "developmental phenomenography" is used for applied research of this kind, one that shares the philosophy, theory and methods common to phenomenographic research (Bowden,

2000b; Green & Bowden, 2009, p. 53). Therefore, the following discussion of theory, methodology and methods relates to phenomenography more generally, with specific reference to developmental phenomenography where relevant. The application of my findings to the professional learning of Australian teachers of STEM subjects will be presented and discussed in Chapter 6 in the context of developmental phenomenography.

3.6.2. Elements of Phenomenography that Inform the Research Design

Due to the unique aim of phenomenography to map variation in the collective experience of a phenomenon, from the perspective of people undergoing the experience, there are methodological implications for how phenomenographic research is practiced (Akerlind, 2005a; Tight, 2016). Akerlind (2005a) asserts the following characteristics of phenomenography have an impact on how research is conducted: its focus is interpretive; findings refer to the collective level of experience; meaning is understood in terms of awareness; meanings are related; descriptions of experience are stripped, and awareness is sensitive to context. These characteristics, along with their underlying assumptions, underpin the study's conceptual and analytical framework which, in turn, have implications for the research design. This includes decisions about the methods of data collection and analysis to be discussed later in this chapter. Each of these characteristics, with reference to this study, are elaborated in the following sections.

Interpretive focus. In Section 3.3 above I situated my study in the interpretive paradigm and explained my interest in exploring and describing the different ways PLOE is experienced, from the perspective of teachers undergoing the experience. To capture these differences, a population of teachers using the Web to learn about STEM education is sampled for variation of experience and demographics. Through a process of communication, participant teachers interpret and describe their different experiences of PLOE. It is then my role as the researcher to interpret and describe their interpretations through a process of data analysis, not to explain the causes of their different experiences (Akerlind, 2005a). As mentioned previously when comparing phenomenography to phenomenography, interpreting the experience of PLOE from the perspective of teachers who have experienced this phenomenon, instead of describing how PLOE is, means taking a second order perspective (Marton, 1981, 1986; Booth & Ingerman, 2015; Limberg, 2008; Pang, 2003; Reed, 2006).

The phenomenographic methods of sampling, interviewing, and interpreting data are presented in the next chapter on Research Methods.

Collective experience. My research focuses on identifying and describing the qualitatively different ways PLOE is experienced by a group of teachers, not individual teachers (Green & Bowden, 2009). This assumes that, from many years of empirical phenomenographic research, "a small number of qualitative different categories" will describe this collective experience of PLOE (Booth & Ingerman, 2015, p. 26; Marton, 1994). Phenomenographic studies commonly reveal four to five different ways a phenomenon is experienced (Booth & Ingerman, 2008). Data are collected from individual teachers yet analysed across the group of teachers, a process that requires a shift in focus from the individual to the collective (Booth & Ingerman, 2015). Since the findings of phenomenographic research refer to the collective level of experience (Akerlind, 2005a; Limberg, 2008; Reed, 2006), it is "methodologically inappropriate" to attribute my findings to individual teachers (Collier-Reed & Ingerman, 2013, p. 2).

Awareness. By choosing phenomenography as a research methodology, the structure of awareness is the lens through which variation of experience is understood, and data are analysed (Harris, 2011). Awareness is a relational term, and refers to everything a person experiences simultaneously, at any point in time (Marton, 2000). However, phenomenographers assume that when people experience something, they cannot be aware of everything, at the same time, in the same way (Akerlind, 2015; Bowden & Marton, 2003; Marton & Booth, 1997; Pang, 2003). There is variation in experience (Marton & Booth, 1997). My understanding of this variation is based on how awareness is structured (Marton & Booth, 1997). In his seminal work, Aaron Gurwitsch (1964) proposed a structure that consists of a theme; thematic field; and margin of awareness (Yoshimi & Vinson, 2015).

In this study, the theme refers to the few, particular features of PLOE teachers are aware of during their experience of it (Bowden & Marton, 2003; Marton & Booth, 1997). The assumption is that teachers will notice, and focus on, certain features, the relationships between these features, and how they make up the phenomenon of PLOE (Marton & Booth, 1997; Reed, 2006). Teachers will experience PLOE differently, and partially, depending on what features they are aware of, at a certain moment in time, in their specific contexts (Akerlind, 2008; Limberg, 2008; Marton & Pong, 2005). To experience PLOE teachers also

need to distinguish this phenomenon from other types of professional learning they have experienced, in their particular contexts (Marton & Booth, 1997). To use the language of phenomenographers, PLOE needs to be delimited and discerned from, and related to, its context (Limberg, 2000; Marton & Booth, 1997; Marton, 2000). The context of experience is the thematic field and includes parts of the experienced world that are not in focus but are relevant to the theme (Marton & Booth, 1997; Yoshimi & Vinson, 2015). In addition to external environments, context also includes perspectives, previous experiences, and future intentions, which all play a part in how phenomena are experienced (Bowden & Marton, 2003; Galin, 1994; Marton, 2000; Patrick, 2000).

I assume teachers experience PLOE in different ways because they focus on different features of the phenomenon according to what is relevant and important to them, their previous experiences and future plans. Anything not relevant to, but which occurs simultaneously with, the thematic field and theme is referred to as the margin (Yoshimi & Vinson, 2015). Exploration of irrelevant, marginal features of awareness lies beyond the scope of this study. Thus, descriptions of variation in the experience of PLOE will refer mainly to the relevant features of this phenomenon that teachers notice on focus on, that move between the theme and thematic field. Awareness is dynamic, and changes at any moment in time depending on what features are focal in awareness (Marton & Booth, 1997; Marton & Tsui, 2004; Yoshimi & Vinson, 2015).

Stripped descriptions. Phenomenographers assume that people experience the same phenomenon differently and are interested in finding the aspects of experience that account for this variation in experience (Akerlind, 2008). In phenomenographic terms, these aspects are often referred to as "critical aspects" (Collier-Reed & Ingerman, 2013, p. 2). In contrast to being 'rich' descriptions of individual experience, phenomenographic findings are presented as reduced or 'stripped' descriptions that emphasise the critical aspects of collective experience (Akerlind, 2008; Marton & Booth, 1997). For example, at the collective level the different ways PLOE is experienced can be described in terms of which "aspects are discerned and appear simultaneously" in teacher's awareness (Marton & Booth, 1997, p. 104; Reed, 2006). Teachers may discern different aspects, or discern different relationships between the aspects, or both. (Bowden & Marton, 2003). However, there is more to

experience than being aware of structural aspects of a phenomenon when a relational view of experience is adopted by phenomenographers (Marton & Booth, 1997).

Related meanings. Experience is conceptualised as having two elements, where the structural aspects of awareness are intertwined with a particular meaning (Marton & Pong, 2005). By adopting a non-dualist, rational view of experience I assume that when PLOE is experienced by teachers, not only are they are aware of certain structural aspects of this phenomenon, but they also attribute meaning to their experience. To use the words of Bowden and Marton (2003) "meaning springs from the aspects of reality which we are aware of and from the way in which we are aware of them" (p. 38). Thus, the different ways that PLOE is experienced can now be conceptualised in terms of the meaning teachers attribute to their experiences intertwined with the structural aspects they discern and are simultaneously aware of (Marton & Booth, 1997; Pang & Ki, 2016). However, to analyse experience at the collective level phenomenographers separate these two related, intertwined elements of experience (Reed, 2006). The process of data analysis is discussed in detail throughout the next chapter on Research Methods. Following the process of data analysis, relationships between meanings will be evident in the findings of a phenomenographic study.

Phenomenographic data analysis yields a set of qualitatively different categories of description, each of which will represent a different way PLOE is experienced at a collective level (Booth & Ingerman, 2015; Marton & Booth, 1997). Since these categories of description represent experiences of the same phenomenon, each one is seen as being "part of a larger whole" (Akerlind, 2008, p. 635). In this sense the meanings of the different ways PLOE is experienced, as described by these categories, are related to each other (Marton & Booth, 1997; Stenfors-Hayes et al., 2013). Each category will have a different meaning, captured in its title, and will be constituted from several structural (critical) aspects that account for variation in how the phenomenon is experienced across a group of participants (Akerlind, 2005a). It is these structural aspects that also account for the relationships between the categories of description (Collier-Reed & Ingerman, 2013; Pang & Ki, 2016).

Structural aspects identified during the analysis of data are also used a "pragmatic construct" to order the categories of description (Pang & Ki, 2016, p. 325). For example, categories may be ordered based on complexity if some are seen as less complex than others due to the structural aspects they contain (Akerlind, 2005a, 2008, 2015; Pang & Ki, 2016;

Stenfors-Hayes et al., 2013). Phenomenographers refer to the combination of logically related categories that describe the different ways a phenomenon is experienced as the *"outcome space"* (Booth & Ingerman, 2015, p. 26; Marton & Booth, 1997, p.125; Reed, 2006).

Context-sensitive awareness. Interpretive researchers seek understanding of people's experience of phenomena in specific contexts (Schwartz-Shea & Yanow, 2012). Since phenomenography is an interpretive methodology, I assume the way PLOE is experienced is sensitive to the specific contexts of Australian teachers learning about STEM education (Akerlind, 2005a; Reed, 2006). In terms of the structure of awareness outlined previously, context refers to parts of the experienced world that are not in focus but those that surround, and are relevant to, the theme of awareness (Marton & Booth, 1997; Yoshimi, & Vinson, 2015). However, context is a term that refers to a combination of "different kinds of context" (Marton & Booth, 1997, p. 87).

Context may be material, such as the environment surrounding the phenomenon a person is experiencing, and/or it may be abstract, such as something that exists in the mind of the person experiencing the phenomenon (Marton & Booth, 1997; Yoshimi & Vinson, 2015). For example, when experiencing PLOE, a teacher's material context refers to what surrounds them while they are engaged in this phenomenon. Their location, the device they are using, the quality of their internet connection, the people they are with, and so on. A teacher's abstract/inner context refers to their thoughts while experiencing PLOE, such as previous experiences of professional learning or of using the internet, their intentions, and their perspectives about this approach to professional learning. Material and abstract contexts influence how a phenomenon is experienced (Bowden & Marton, 2003; Galin, 1994; Marton, 2000; Patrick, 2000). As mentioned in the previous section on awareness, a change in context may have an impact on the features of a phenomenon a person is aware of at a certain moment in time. In this sense, a way of experiencing a phenomenon is seen by phenomenographers as being context sensitive (Akerlind, 2005a).

These characteristics, assumptions, and concepts, along with the principles of developmental phenomenography, have implications for how this study is designed.

3.7. Phenomenographic Research Design

The purpose of using developmental phenomenography, briefly introduced in Section 3.6.1, is to produce findings that can be used to address an educational issue (Green & Bowden, 2009). It is my intention that findings from this research will have a practical application to the professional learning of teachers. In phenomenographic terms, my findings can be used to help K-12 teachers of STEM subjects discern the phenomenon of PLOE in new and possibly more meaningful and powerful ways (Collier-Reed et al., 2009). To generate findings applicable to this purpose and intent, my research design was based on the main research question: What are the qualitatively different ways that professional learning through Open Education is experienced by Australian teachers involved in STEM education? This question was approached through three sub questions:

RQ1: What are the different meanings Australian teachers involved in STEM education attribute to the experience of PLOE?

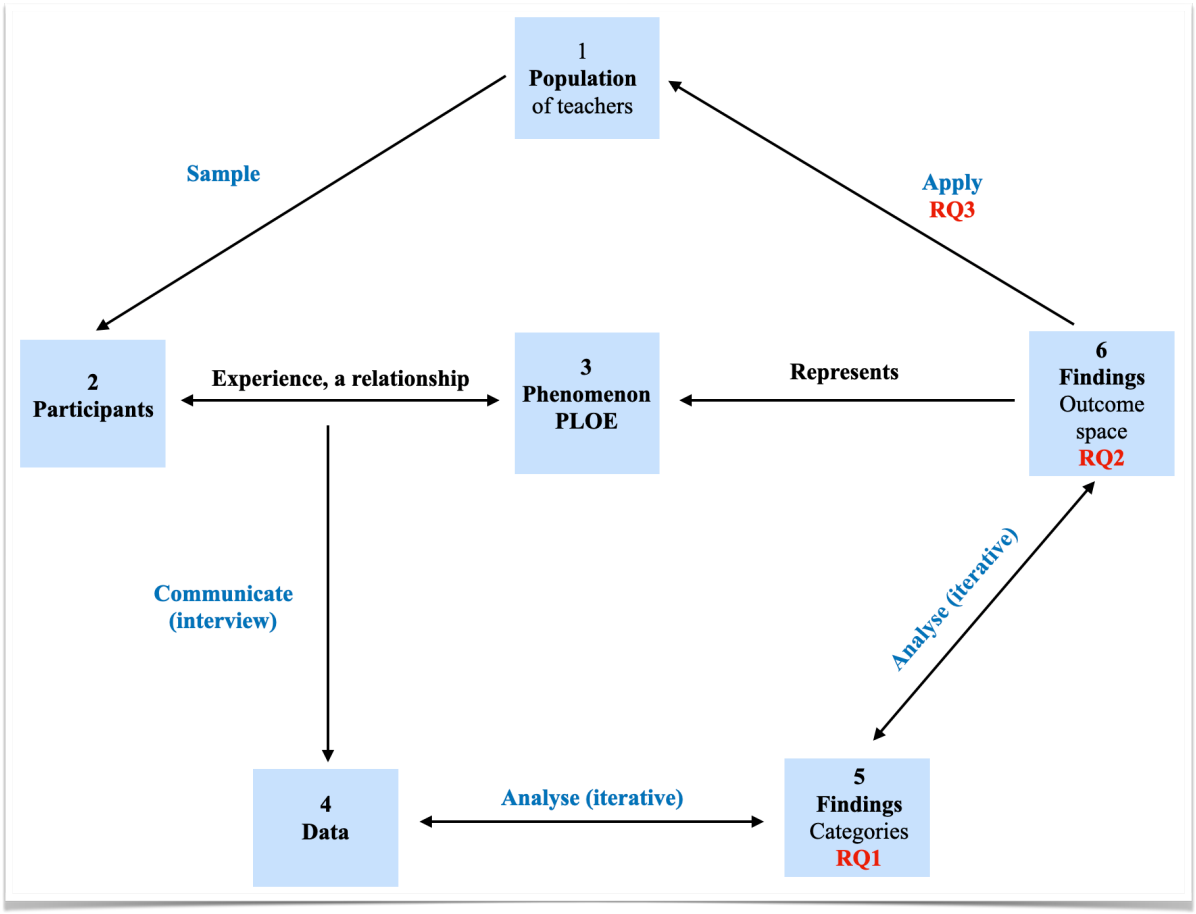
RQ2: What aspects of PLOE are critical to the different ways this phenomenon is experienced by Australian teachers involved in STEM education?

RQ3: How can the new knowledge gained from RQ1 and RQ2 be used to design professional learning experiences for Australian teachers involved in STEM education?

Figure 3.2 below is a diagrammatic representation of the basic elements of my study, showing how they work together to yield answers to these research questions.

Figure 3.2

Elements of the Research Design



Each of these elements is now briefly described, beginning with the population of teachers at the top of Figure 3.2. then moving in an anti-clockwise direction around the diagram.

1. The **population** of Australian teachers of interest for this study are K-12 teachers engaged in PLOE to learn about STEM education.
2. **Participants** are sampled from this population to capture variation in their experiences of a phenomenon.
3. The **Phenomenon** experienced by teachers is Professional Learning through Open Education **(PLOE).** Experience of this phenomenon is relational, and is explored from the perspective of teachers.
4. **Data** are generated through a process of communication (phenomenographic interview) between the researcher and participant teachers, during which teachers

reflect on and interpret their experiences of PLOE. It is assumed that experience is sensitive to context, and that awareness is dynamic and captured at the time of the interview. Therefore, in a phenomenographic research design there is only one data collection phase in which individual teachers describe their unique ways of experiencing PLOE. Additionally, this is the only source of data used for analysis. Phenomenographers are interested in variation in the collective experience of a phenomenon, therefore data are pooled before the iterative process of data analysis begins. From this point, there is a shift in researcher focus from the experience of individuals to the collective experience of PLOE across a group of participant teachers.

5. **Findings (Categories).** The analytical process of separating the meaning of experience from the structural aspects of awareness results in the constitution of a small number of qualitatively different categories of description. In keeping with the interpretive paradigm this study is situated within, these categories are not determined in advance. They represent the different meanings attributed to the experience of PLOE across the group of teachers and provide the answer to RQ1: What are the different meanings Australian teachers involved in STEM education attribute to the experience of PLOE?
6. **Findings (Outcome space).** Further analysis of data reveals relationships between the different categories. These relationships are due to critical aspects found in each category. These aspects provide the answer to RQ2: What aspects of PLOE are critical to the different ways this phenomenon is experienced by Australian teachers involved in STEM education? The critical aspects, categories, and relationships between them come together to form the outcome space. This represents the phenomenon of PLOE.

The research design is completed through the practical intent of developmental phenomenography addressed by RQ3: How can the new knowledge gained from RQ1 and RQ2 be used to design professional learning experiences for Australian teachers involved in STEM education? The answer to this question can be applied to the **population of teachers** from which the original sample was drawn. In the next section I present my argument for the trustworthiness of this research design, to be judged by others against certain criteria

developed within the phenomenographic and broader interpretivist, qualitative research communities.

3.8. In Defence of the Research Design

In this section I discuss the concept of trustworthiness in the context of the research design presented in the previous section. To reiterate, this study is situated in the interpretive paradigm. It is concerned with interpretation and description of the different ways the phenomenon of PLOE is experienced, form the perspective of participants undergoing the experience. Therefore, the decisions I made to construct this research design are shaped by the philosophical assumptions of interpretivism described previously in Sections 3.2 and 3.3. These assumptions, and the criteria used to judge the trustworthiness and rigour of interpretive qualitative research, differ to those underpinning research conducted in the scientific (commonly referred to as the positivist) paradigm (Lincoln & Guba, 1985). Instead of the conventional criteria of validity, reliability and generalisability used in positivist research, the criteria of credibility, dependability, and transferability (respectively) are commonly applied to research of an interpretive, qualitative nature (Collier-Reed et al., 2009; Lincoln & Guba, 1988; Schwandt et al., 2007; Schwartz-Shea & Yanow, 2012). Each of these is now briefly discussed with reference to this study.

Credibility. Credibility refers to whether the reality of teachers' experiences, described from their perspective and interpreted by the researcher, corresponds adequately to the findings I present in Chapter 5. Collier-Reed et al. (2009) suggest the "outcome of phenomenographic research can be taken seriously" if the researcher considers content-related credibility, credibility of method and communicative credibility (p. 7). Content-related credibility refers to the researcher being familiar with their area of research. For instance, I have experience of teaching in the area of secondary STEM education, of learning on the Web and of professional learning more generally. My previous experience and knowledge of relevant content are made explicit in Chapter 1 where I situate myself in this research. This familiarity of content enabled me to understand, and to be open to, the different ways teachers described their experience of PLOE. However, it also had a potential impact on the conduct of this study, and its findings. The reflexive stance I took towards the impact of my presence is addressed below.

Credibility of method refers to the way a study is designed and conducted (Collier-Reed et al., 2009). For a study to be credible there needs to be alignment between the research questions, the object of the study, the methods of data collection and analysis, and the findings (Collier-Reed et al., 2009; Sin, 2010). In defence of my research design, I have justified throughout this chapter my reasons for situating this study the interpretive paradigm; for choosing phenomenography; for the theoretical and methodological decisions underpinning participant selection, data collection and analysis, and the presentation and application of the findings. From this discussion the different elements of the research design were identified and are represented in Figure 3.2 which shows how these elements, along with the research questions, are related and connected as a "cohesive whole" (Creswell, 2007, p. 42).

This connectedness will become evident when I describe the Research Methods in the next chapter, and present the Findings in Chapter 5. For example, to capture variation in the ways PLOE was experienced, participant teachers were sampled for variation of demographics, were interviewed to elicit variation of experience, data were analysed to identify patterns of variation, and variation in the meaning of experience is captured in the qualitatively different categories of description. Finally, communicative credibility refers to researchers arguing for, persuading others about, and defending the interpretations they propose, because no interpretation of data is 'true', 'right' or 'correct' in the interpretive paradigm (Akerlind, 2005d; Collier-Reed et al., 2009). I will argue for my interpretation of the data in Chapter 5 when I present the Findings and in Chapter 6 during the Discussion.

Dependability. As an interpretive researcher I am interested in whether other people can understand my meaning-making process, not if they can replicate my findings, in different contexts, at different times (Gasson, 2004; Schwartz-Shea & Yanow, 2012). I will assure the reader that my findings are not "completely idiosyncratic" to this study, but show they are constituted through procedures recognised within the phenomenographic research community (Marshall & Rossman, 2016, p. 261). In doing so other researchers, with knowledge of the same phenomenon, should recognise the phenomenographic journey described in this thesis. The strategies I take to ensure a careful, consistent and transparent approach to this study are described in the next chapter on Research Methods; so too is my thinking, documented in descriptions of how I reached my findings. In addition to being

explicit about how I reached my findings in Chapter 4, interview extracts are included as empirical evidence to support my interpretations in Chapter 5. To enhance the dependability, thus the trustworthiness of my findings, I was also mindful of Marton and Booth's (1997) recommendations for judging the quality of a phenomenographic outcome space. Firstly, the categories of description need to be logically related; secondly, they need to be parsimonious (the different ways PLOE is experienced must be described by the minimum number of categories) finally, each category must be qualitatively different and reveal something distinctive about the experience of PLOE. I will return to these criteria when presenting my findings in Chapter 5.

Transferability. Transferability is the extent to which the research findings can be applied in different contexts with different people (Lincoln & Guba, 1985). Transferability is a trustworthiness criterion for ensuring the quality of a study (Collier-Reed et al., 2009). It is also a criterion that drives the purpose of this study. This research aims to produce new knowledge for the purpose of application and change in the specific context of Australian K-12 teacher's professional learning and STEM education. In the research design this criterion relates to the final stage of developmental phenomenography in which the researcher's intention is for the findings to be applied to the problem of practice from which the research originated (Green & Bowden, 2009). Like any developmental phenomenographic study, the researcher's intent underpins every element of the research design. One strategy embedded in this design to enhance the transferability/applicability of my findings is to maximise variation in the selection of participants (Larsson, 2009). This strategy, which includes providing information about participant teachers and their contexts, is elaborated in the next chapter on Research Methods. A framework for the transferability of my findings to the professional learning of Australian teachers of STEM subjects is articulated in the Discussion chapter, Chapter 6.

Reflexivity. Reflexivity is related to my inevitable influence on the findings of this interpretive, qualitative study. It is a concept that refers to researchers acknowledging that their biases, motivations, beliefs, interests, experiences, and perspectives may have an impact on, and shape, their findings (Berger, 2015; Lincoln & Guba, 1985). Bowden (2005) emphasised that researchers have a relational, not independent, role in phenomenographic research. In fact, as the solo researcher I am particularly aware of my influence on every

aspect my research design and see my findings as being relational rather than totally independent of my conduct. Therefore, as Lincoln and Guba (1988) stated, I have "an obligation to be self-examining, self-questioning, self-challenging, self-critical, and self-correcting" (p. 11). This is the nature of being reflexive. According to Schwartz-Shea & Yanow (2012):

> Reflexivity is "a researcher's active consideration of and engagement with the ways in which his own sense-making and the particular circumstances that might have affected it, throughout all phases of the research process, relate to the knowledge claims he ultimately advances in written form. (Schwartz-Shea & Yanow, 2012, p. 100)

I interchange the concept of reflexivity with "interpretive awareness", a commonly used term in phenomenography that refers to researchers acknowledging and explicitly attending to their subjectivity throughout the research process (Sandberg, 2000, p. 14). Adopting a reflexive stance enhances the quality and trustworthiness of interpretive research (Berger, 2015; Schwartz-Shea & Yanow, 2012).

I first enacted reflexivity towards this research design when I positioned myself as "The Biographically Situated Researcher" in Chapter 1, and acknowledge, rather than deny and ignore, what I bring into this research and the impact I may have on the findings. I have previous experience of teaching in STEM subject areas, of professional learning, and learning about STEM education through Open Education, all of which have the potential to impact on my focus, which is on the relationship between participants and the phenomenon of PLOE. The strategies I used to minimise my impact on the process of recruitment, sampling and communication with participants, and the analysis and interpretation of data, are described in the next chapter on Research Methods. For example, during the data collection phase I used an interview guide as a means of minimising my input into the conversation. During the data analysis phase I used only the empirical data from interview transcripts and was open and receptive to the different ways teachers described their experiences of PLOE.

According to Berger (2015) reflexivity also keeps "the process of research ethical" (p. 221). With reference to the research design, I was mindful of my ethical conduct and issues that could arise when recruiting and communicating with teachers; storing and analysing data obtained from teachers; and writing about my findings. The strategies I used to

ensure my ethical conduct, such as avoiding coercion, seeking informed consent, protecting teacher anonymity and confidentiality of data, are also detailed in the next chapter on Research Methods. Overall, in the next chapter I document how reflexivity is enacted so others can judge how I minimised my impact on the research process to enhance the trustworthiness of the findings that are presented in Chapter 5.

3.9. Chapter Summary

In this chapter I have described and justified how my research was conceptualised and designed in order to answer the research questions. I presented the interpretive qualitative research design based on my philosophical beliefs, the issue of teachers experiences of professional learning driving this research, and on the intention for my findings to be applied to the area of professional learning for Australian teachers of STEM subjects. Phenomenography was selected as an appropriate methodology, enabling me to research the different ways the phenomenon of professional learning through Open Education was experienced across a group of Australian teachers of STEM subjects. The core characteristics of phenomenography, along with its theoretical elements, were combined with the methods of data collection and analysis to present my research design framed by developmental phenomenography. In the next chapter I will outline the methods used to conduct the study, including sampling data, data collection and data analysis, and interpretation.

CHAPTER 4. RESEARCH METHODS

This is the second of two chapters that collectively describe and justify the design and conduct of this study. In the previous chapter, the research design was presented, with developmental phenomenography selected as an appropriate theoretical and methodological framework compatible with the researcher's worldview, and appropriate to answer the research questions. This chapter begins with an outline of the data collection process, including sampling decisions, the types of data collected, and the tools used for its collection, presented in a sequence of three phases: the sampling and recruitment, interview and data analysis phases. The description of each phase dovetails with the components of a phenomenographic study incorporated into my research design in Chapter 3: the phenomenon; a group of participants; a way to communicate; a process to analyse the data; and the researcher (Bowden, 2005).

It is critical in a phenomenographic study to build on accepted phenomenographic practice, particularly with respect to the processes used to analyse and interpret the data. This chapter will show how this has been achieved, with reference to variations and commonalities in the phenomenographic practice of data analysis. It is also critical for any researcher to be mindful of the fundamental ethical principle of research, which is to do no harm (Simons, 2009). In accordance with this principle, the University of Southern Queensland's Ethics Committee granted full ethical approval for this research (USQ Ethics Approval Number: H15REA257). Ethical considerations are discussed throughout this chapter where appropriate, with reference to the interaction with participants, keeping them informed, and protecting their anonymity, privacy, and confidentiality. The chapter concludes with a reflection by the researcher on the role of 'self' in the research process.

4.1. Methods

The following sections describe the methods as they occurred in a sequence of three phases: pre-interview, interview, and post interview. The tools used to collect data are outlined first so the data collection process is clear.

4.1.1. Overview of Research Phases, Sampling Decisions and Data Collection Tools

Three types of data were required in this study to answer the research questions: information about the demographics of the sample population of teachers; preliminary

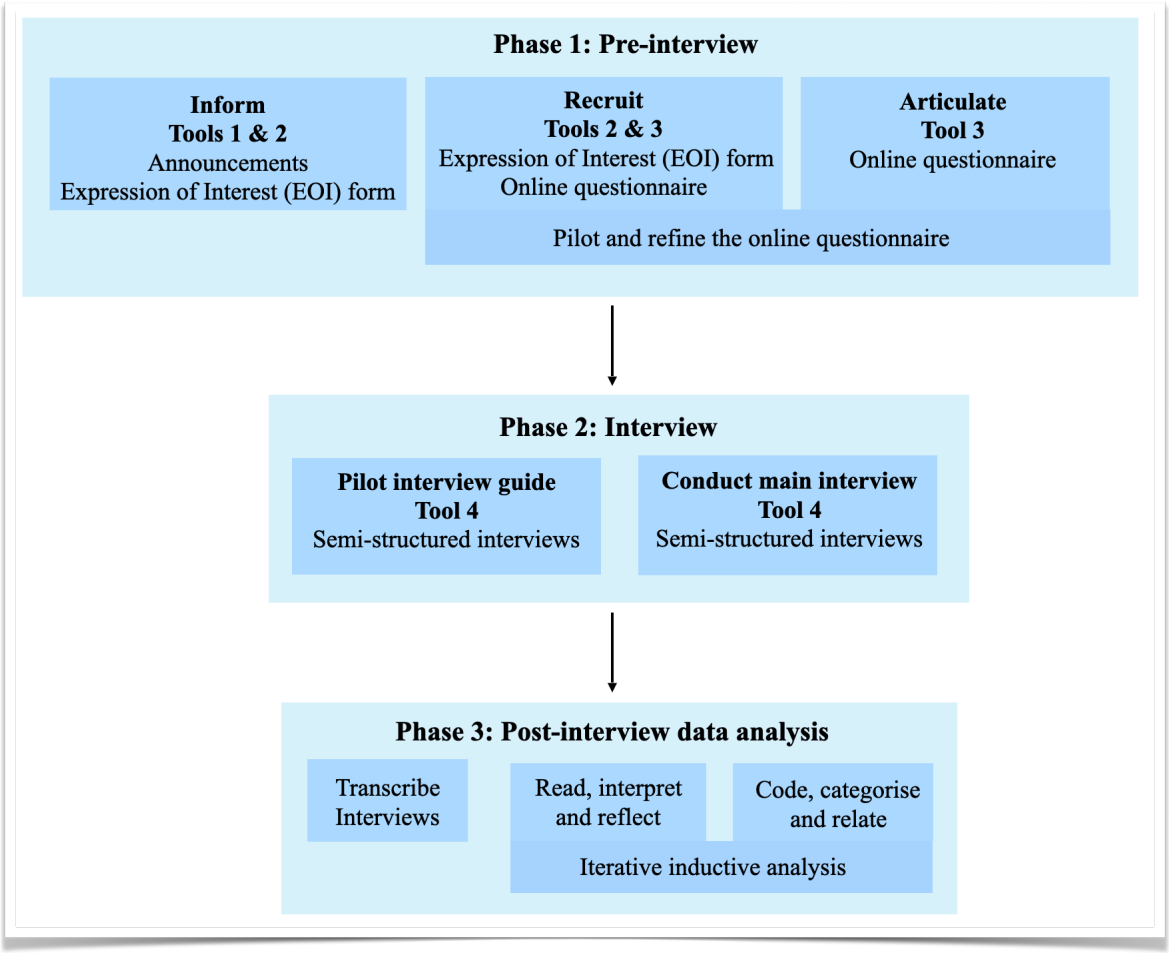
information about the teachers' prior knowledge of the phenomenon; and descriptions of the teachers' experience of the phenomenon upon which the data analysis and phenomenographic outcomes are based. The tools utilised to achieve the collection of this information, and the reasons for doing so, are described in detail in different sections of this chapter. Briefly, they include the following:

1. **Announcements**. Announcements were made via social media to inform teachers about the study and invite expressions of interest to participate.
2. **Expression of Interest (EOI) form**. This was completed by teachers who were interested in voluntarily taking part in the research. A total of 48 teachers completed the EOI form. They were then emailed a link to an online questionnaire.
3. **Online questionnaire**. A questionnaire was used to collect two types of data. Firstly, demographic information enabled me to confirm that teachers met the criteria for participation in this study, and to ascertain there was adequate variation in the sample demographics. Secondly, preliminary answers to questions about teachers' prior knowledge of PLOE enabled me to derive a common language to communicate with teachers about their experiences of this ill-defined and nebulous phenomenon. This online questionnaire was piloted by five teachers and the questions were refined prior to administration to the remaining 43 teachers. A total of 35 teachers completed the final questionnaire.
4. **Semi-structured, phenomenographic interview.** This was the main data collection tool as it enabled me to collect data about the experiences of each teacher. Of the 35 teachers who had completed the questionnaire, 20 agreed to be interviewed. Three teachers were asked to pilot the interview and the questions were refined prior to interviewing the remaining teachers in the sample. Data from the pilot interviews were not included in the final analysis. One teacher's interview was removed from the sample because it was discovered that she had not disclosed her current occupation as a tertiary educator of K-12 teachers prior to the interview. Therefore, she did not meet the criteria for inclusion in this study. This left a total of 16 teachers who participated in the phenomenographic interviews and whose data were analysed and included in the outcome space.

Figure 4.1 shows how these four tools operated within a three-phase sequence of the research methods: the pre-interview, interview, and post-interview phases.

Figure 4.1

A Representation of the Research Phases of this Study and the Data Collection Tools



Each phase has various aspects that will be described in the following sections. Theoretical justification will generally be presented first followed by a description of the decisions and the processes undertaken in this study.

4.1.2. Phase 1: Pre-interview

As described in Chapter 3, the focus of this study is on the relationship between teachers and the phenomenon of professional learning through Open Education (PLOE), not the phenomenon itself. Collecting data about this relationship was accomplished through interviews, which is the most commonly used data collection strategy in phenomenographic research (Bowden, 2005; Bruce, 1994; Larsson & Holmström, 2007). The nature of the

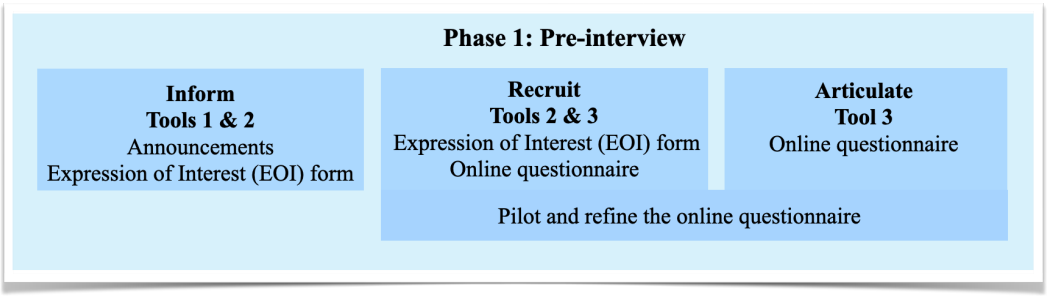
interview will be described further in Section 4.1.3. However, before interviews can be successfully conducted, it is important to set the stage for them, and Phase 1, the pre-interview phase, is the way in which this was achieved. There are three parts to Phase 1, each having a specific purpose:

1. To **inform** teachers in my digital network about the questionnaire
2. To **recruit** teachers through two purposeful sampling strategies (Patton, 2002)
3. To establish and **articulate** a common language for the researcher and teachers to communicate about the phenomenon of PLOE. This common language was used to develop and refine an interview guide.

Consequently, Phase 1 was about contacting and recruiting the second common component of a phenomenographic study, the participants. Figure 4.2 shows how these three parts sit within Phase 1 of the research methods sequence.

Figure 4.2

A Representation of the Three Parts of Phase 1 and the Data Collection Tools

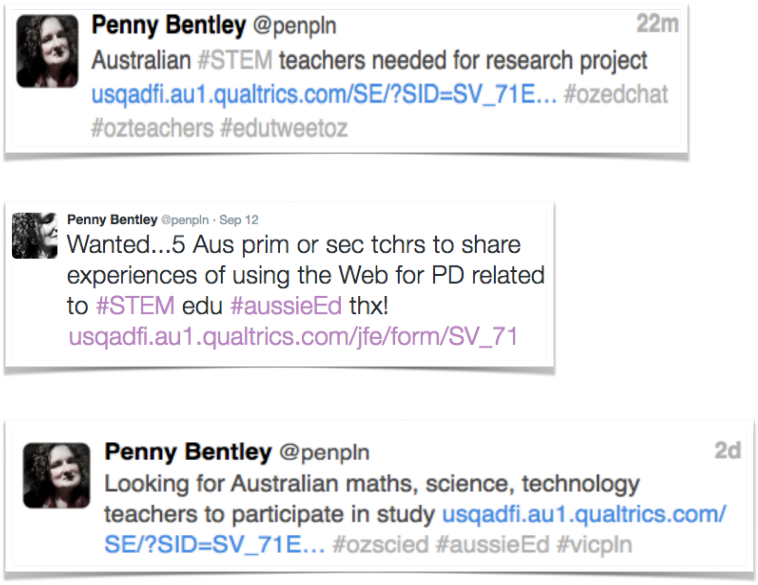


Each step in Phase 1 is now described in detail in the interests of transparency.

Step 1 – Inform. From February 2016 to September 2016, I used my social network to inform Australian teachers of STEM subject areas about my study. Qualtrics, an online survey tool, was used to create an Expression of Interest (EOI) form (Appendix 1). A link to this online form was circulated via announcements on the social media platforms Twitter and Facebook. For wider reach, the hashtags #vicpln, #ozedchat, #ozscied, #aussieEd, #ozteachers, #edutweetoz, #STEM and #aussieEd were included in tweets and Facebook posts. The collection of images in Figure 4.3 below shows examples of how social media was used to inform teachers about this study.

Figure 4.3

Three Examples of Social Media Posts Aimed to Inform Teachers About this Study



Including hashtags in tweets enabled me to approach teachers indirectly on Twitter. In doing so I fulfilled my ethical responsibility as the researcher not to coerce or pressure teachers into participating in this study.

Step 2 – Recruit. Teachers whose interest was piqued by the announcements on social media could self-nominate for the study by completing the EOI online. However, self-nomination does not always guarantee that an appropriate selection of participants will be found, yet this is a key methodological requirement. Phenomenographers are interested in variation, not similarity of experience; therefore, sampling of a population is conducted to maximise variation of experience (Akerlind, 2005a; Green, 2005). It is assumed that variation in the characteristics of participants helps to maximise variation of experience captured during the interviews (Akerlind, 2008; Stenfors-Hayes et al., 2013). Therefore, selection of participants with diverse demographic characteristics is assumed to reflect variation within the population from which they are selected (Akerlind, 2005a). This purposeful sampling strategy is referred to as maximum variation sampling (Patton, 2002). It should be noted that not all possible ways of experiencing a phenomenon are necessarily captured by this kind of sampling, therefore, the outcomes of a phenomenographic study cannot be generalised to a population. In this sense, purposeful sampling is different from probability sampling, a

strategy used by researchers who randomly select larger numbers of participants to ensure the sample represents a larger population for the purpose of generalisation (Patton, 2002).

In addition to selecting appropriate participants, there needs to be a sufficient number of participants to yield variation of experience. Traditionally, the number of participants in phenomenographic studies is small (Akerlind et al., 2005). Since phenomenographic data analysis is time consuming, solo researchers choose the smallest number of participants they assume will represent variation of experience in the population they were chosen from (Akerlind, 2007). Some empirical evidence indicates 10 participants are adequate (Akerlind, 2007). Other evidence suggests that 15 to 20 is the ideal, although 10 to 15 participants would be the minimum to create a reasonable chance of finding variation of experience (Trigwell, 2000). Bowden and Green (2005) recommend samples of 15 to 30 participants, but acknowledge a smaller sample size is appropriate. If researchers believe they do not have enough participants to find variation of experience, snowball sampling is another strategy for purposefully selecting participants (Patton, 1990).

Snowball sampling involves the researcher finding more participants by asking a number of existing participants, with whom contact has already been made, to recommend others who would be suitable for the study. In the end, even if more variation was possible, the results of a phenomenographic study are still valid (Akerlind, 2007). It just means other ways of experiencing a phenomenon are not evident in the data and are still to be found (Akerlind, 2007). With these methodological principles in mind, the purpose of the recruitment step in Phase 1 was to recruit teachers using both of these purposeful sampling strategies: maximum variation sampling and snowball sampling. In all, 48 teachers responded to the EOI form. To recruit this many teachers, snowball sampling was required, where teachers who responded initially to the EOI were asked to inform other teachers in their social media network. Snowball sampling continued until no more EOI forms were received.

At this point, the online questionnaire was piloted by the first five teachers to respond to the EOI form. This questionnaire was developed in, and distributed through, the Qualtrics platform and took 10 to 15 minutes for participants to complete. One purpose of collecting this data was to verify that the sample of teachers participating in this study showed variation in demographic characteristics (Akerlind, 2008). Secondly, I needed to ensure that I was able to interview teachers who had experience of PLOE so that my research findings could be

used to fulfil the pedagogical aim of developmental phenomenography. The online questionnaire was therefore a tool for ensuring that my participants were appropriate for both purposes.

The online questionnaire was developed with inspiration from researchers at The Open Education Research Hub (Farrow et al., 2016). These researchers designed and used questionnaires to collect data on the impact of Open Educational Resources (OER) on teaching and learning (Farrow et al., 2015). I built upon their research work, adapting it as an OER, to fit the purpose of my own research. Piloting the online questionnaire with five teachers enabled me to elicit feedback on whether the questions made sense to teachers, how the questionnaire flowed from question to question, the time it took to complete, and whether the formatting was mobile friendly. Several questions needed re-formatting, but most were clearly read on mobile devices such as smart phones, iPads and other tablets. (Some further refinement was needed to clarify the use of several terms related to the phenomenon of PLOE. This process is detailed in the next section, Phase 1: Part 3 – Articulate.). After some refinement, all 26 questions were included in the final online questionnaire entitled Open Educational Practices and Australian STEM Teachers' Professional Learning (Appendix 2). The remaining 43 teachers were then sent an email (Appendix 3) containing a link to the finalised version of the questionnaire with a Participant Information Sheet attached (Appendix 4). As the researcher, my ethical obligations of collecting data from participants were met by:

- Seeking informed consent prior to collecting and using data
- Providing Participant Information Sheets to make explicit all relevant details regarding this study
- Informing teachers the process was entirely voluntary and they were free to withdraw at any time
- Minimising time commitment and inconvenience
- Informing teachers that confidentiality of data and privacy will be respected during and after the study
- Secure storage of data

Responses to the questionnaire (n=35) were captured in and downloaded from Qualtrics. However, of the 35 teachers who responded to the questionnaire, only 20 agreed to be interviewed. Of these 20 teachers, three were asked to pilot the interview guide, a process described below in the section Phase 2: Interview. Another teacher was ‘lost' from the final interview sample because she did not disclose her current occupation as a tertiary educator of K-12 teachers prior to the interview. Therefore, she did not meet the criteria for inclusion in this study. This left a final total of 16 participant teachers who were interviewed in Phase 2, and whose data were analysed in Phase 3. This number exceeds the minimum of the recommendations of 10-30 participants in the literature discussed above. Table 4.1 below shows the demographic characteristics of the16 teachers who were interviewed in Phase 2, and whose data were included for analysis in Phase 3.

Table 4.1

Demographics of the Interview Sample of Participants (n=16)

Characteristic	**Demographics of the interview sample of participants (n=16)**
Geographic location	56% Victoria 19% New South Wales 19% Queensland 6% Western Australia
Gender balance	56% female 44% male
Age	38% between 50-59 years 31% between 30-39 years 19% 60 years or more 6% 20-29 years 6% 40-49 years
Years of teaching experience	56% mid career teachers between 7-18 years 31% late career of 19 years and more 13% early career teachers between 1-6 years
School location	38% in regional cities 25% metropolitan areas 25% in capital cities 13% in rural or remote areas
Teaching position	63% permanent, full-time 19% contract 19% part time
Education system	63% secondary school teachers 31% primary school teachers 6% of the participants worked across both sectors
Learning areas (teachers worked in one or more learning areas)	77% worked in Science learning areas 56% in Technology related learning areas (Information and Communication technology, Design and Technologies and Digital Technologies) 50% in Mathematics

This sample of 16 participants was characterised by teachers of STEM subject areas who were qualified, registered, and employed in the primary and secondary sectors of Australian schools (according to the registration requirements of the Australian State or territory where they were located). Teacher librarians were also included as they are registered teachers who work in partnership with teachers learning about STEM education. These teachers showed a range of demographic characteristics such as age, basis of employment, years of teaching experience, subjects and year levels taught, and school location. With variation across this range of characteristics, I assumed teachers within this sample will experience PLOE in different ways, and represent variation in the population from which they came. This links to the third and final step in Phase 1, which explains the strategy adopted to limit the boundaries of the phenomenon under investigation, an important methodological step where phenomena such as PLOE are nebulous and ill-defined (Collier-Reed & Ingerman, 2013).

Step 3 – Articulate. Phenomenographers focus on variation of experience, conceptualised as the different relationships individuals have with a phenomenon (Marton & Booth, 1997). The phenomenon may be specific, general, abstract, concrete, well defined or ill-defined, and is not always easy to discuss (Dringenberg et al ., 2015). Regardless of the nature of the phenomenon, it is important the researcher establishes that, before the collection of interview data begins, everyone participating in the study is able to discuss experiences of the same phenomenon (Collier-Reed & Ingerman, 2013). This was the third purpose of piloting, refining and collecting data via the online questionnaire.

Professional learning through Open Education (PLOE) is not defined in the literature. Therefore, in Chapter 2 (Section 2.5.4) I explored the nature of PLOE as a phenomenon bounded by the concepts of professional learning, the open Web, and Open Education.

To reiterate, in the context of this study:

- Professional learning refers to learning that results from any experience through which teachers themselves perceive they have learned something related to their roles as K-12 teachers involved in STEM education.
- The open Web is the digital context for teachers' professional learning that includes Web tools, platforms, resources, people and culture.
- Open Education is interpreted as the Open Educational Practices (OEP) of teachers using the open Web as a context for professional learning.

Thus, an understanding of PLOE relates to a broad definition of professional learning, the technical and social infrastructure of the open Web as a learning environment, and an understanding of Open Education as Open Educational Practices (OEP). I needed to establish and articulate a common language to communicate with teachers about their experience of this ill-defined phenomenon for Phase 3: Interview.

Piloting the online questionnaire revealed that teachers were not familiar with the terms Open Educational Practices (OEP) or Open Educational Resources (OER). Therefore, refining the questionnaire included a change in wording from 'professional learning through OEP' to 'professional learning on the open Web'. In doing so I interpreted teachers' actions on the open Web as OEP. Similarly, due to lack of familiarity among teachers with the term Open Educational Resources (OER), the wording was changed to 'resources found on the open Web'. The final version of the online questionnaire was then used to gain additional information about teachers' prior knowledge of professional learning on the open Web. Generally, teachers used the words 'personal', 'social', 'active' and 'informative' to characterise this phenomenon. From this response I was confident that I was communicating with teachers about the phenomenon I wanted to investigate. Information gained from the online questionnaire was used to inform the development of an interview guide, consisting of an introductory statement and interview questions. This guide was piloted and refined the next phase, which will now be explained.

4.1.3. Phase 2: The Phenomenographic Interview

Communication via interviews is the most common method used by phenomenographers to explore the relationship between participants and a phenomenon in the world, and to collect data for analysis (Ashworth & Lucas, 2000; Collier-Reed & Ingerman, 2013; Marton, 1986; Tight, 2016). Interviews can be highly structured, semi-structured or open (Willis, 2007). The purpose of conducting a phenomenographic interview was to encourage teachers to reveal and express their different ways of experiencing the phenomenon of PLOE. Therefore, it was not methodologically appropriate to use a highly structured interview format. Nor was it suitable to conduct an open interview, without an interview guide, that could drift away from the required focus of a phenomenographic interview (Somekh & Lewin, 2011). To elicit variation of experience, I needed to ask some open-ended questions, while maintaining focus on the relationship between the individual teacher and the phenomenon of PLOE. Thus, a semi-structured interview format was considered to be the most appropriate.

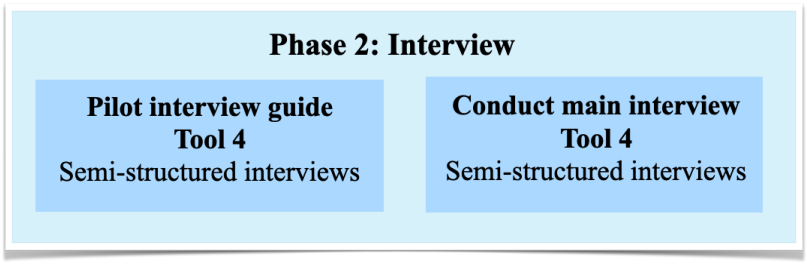
Before main interviews were successfully conducted, it was important to pilot the interview guide that was developed during Phase 1. There are two steps in Phase 2 of this research methods sequence, each having a specific purpose:

1. To pilot, reflect on, and modify the interview guide
2. To conduct the semi-structured interviews for the main study

Figure 4.4 shows how these two parts sit within Phase 2 of the research methods sequence.

Figure 4.4

A Representation of the Two Parts of Phase 2 of the Research Methods Sequence



Step 1 - Pilot Interview Guide. Since the overall success of phenomenographic research is determined by the quality of phenomenographic interviews, it is critical they are conducted properly (Green & Bowden, 2009). As a novice researcher, I was very aware of the need to conduct pilot interviews to learn, practice, and improve my interviewing skills (Akerlind et al., 2005; Bowden, 2005). Additionally, the purpose of conducting a pilot study was to:

- Develop an effective introductory statement for the interview guide (Green & Bowden, 2009)
- Ascertain if the interview guide elicited variation of experience (Akerlind, 2005c), and the desired information to answer the research questions (Bowden, 2005)
- Improve the overall quality of data collected (Walsh, 2000)

In all, three pilot interviews were conducted, and I was able to ask two of the teachers for direct feedback (Appendix 5). The third teacher did not have time after the pilot interview to offer feedback. The pilot interviews were conducted with participants following a similar protocol to that developed for the main study, and the same planned inputs were used for all pilot interviews (Bowden, 2005). The feedback received generated several insights that enabled me to improve my interview questions, protocol and technique.

Firstly, my style of open-ended questioning made sense to the teachers but could be tiring, repetitive, and seemed to have no order. However, this is the nature of a phenomenographic interview, where prompting and probing is used by the researcher to maintain focus on the relationship between teachers and the phenomenon of PLOE. In that sense, I was confident the pilot interviews elicited good data about experience of a phenomenon. As a consequence of this feedback, when conducting the main interviews, I was mindful of signs of fatigue and frustration in participant teachers. Secondly, teacher feedback revealed that I needed to further articulate the nature of the phenomenon of PLOE to elicit the required data. I assumed the terms ‘professional learning’ and the ‘open Web’ could be explored and clarified through a set of general, open-ended questions as part of the introductory statement prior to asking teachers to reflect on an a specific experience of their choice. This led to gaps in communication and repetition throughout the interview when these terms, along with the terms ‘STEM’ and ‘experience’, were raised. Therefore, the

introductory statement was refined by removing the introductory questions and making explicit reference to how these terms would be used throughout the interview.

With respect to the term 'professional learning', in the pilot study I asked participants to reflect on a recent experience of 'effective' professional learning on the open Web. However, in their feedback, teachers revealed a struggle to recall examples of 'effective' professional learning. I discovered that teachers may not be having professional learning events that could be described this way. Professional learning on the open Web is informal, self-directed, and more likely to be continuous and serendipitous, rather than made up of a series of pre-planned 'events' that could be described as effective or ineffective. I needed to view, and communicate, professional learning differently, and think of ways to elicit learning experiences of this kind. Therefore, the final interview guide included explicit reference to how the term professional learning would be used during the interview and the word 'effective' was omitted to enable participants to describe any experience they considered to be professional learning, whether effective or not. It is important to note that these terms do not define the phenomenon of PLOE; rather, they provide a means of communication about a phenomenon that is yet to be defined. When doubt arose during the main interview (as described in the next step), I referred to these terms in the interview guide. This ensured consistency of information provided to teachers, less repetition and fewer questions.

As a result of my critical reflections, the final interview guide was prepared (Appendix 6). I was now confident the interview guide would elicit the necessary data capable of answering the research questions. The remaining 16 teachers who completed the online questionnaire, who agreed to be interviewed, received a second email (Appendix 7) containing a link to the online consent form with a Participant Information Sheet attached (Appendix 8). Once again, the ethical obligations of collecting data from participants was met by keeping teachers informed about the process. Congruent with the advice from the literature, none of the data from pilot interviews were included in the final analysis (Bowden, 2005) as it had been collected at a different time to the main interviews and using differently worded instruments.

Step 2 – Conduct the Main Interview. The outcomes of phenomenographic research depend on how the experience of PLOE is described and must, as Ashworth and Lucas (2000) say, "be grounded in the lived experience" of teachers (p. 297). Steps were taken throughout the interviews to make sure the experience of teachers remained in focus. More specifically, I took steps to encourage teachers to reflect on their experiences of this phenomenon and to collect data from their perspective (Marton & Booth, 1997). I began every interview with the same introductory statement (Green & Bowden, 2009). The interview was then guided by the pre-planned, open-ended questions in the interview guide (Akerlind et al., 2005). This semi-structured interview format enabled teachers to communicate their point of view, as fully as possible, about the contents of the introductory statement (Bowden, 2005). My intention of using open-ended questions was to give teachers a choice over how they wanted to answer the question (Marton, 1986). I also wanted to encourage teachers to reflect on, and offer their own perspectives about, their experiences of PLOE (Akerlind, 2005a; Dall'Alba, 2000). To elicit further information, teachers' responses were probed with more questions (Bowden, 2005).

For example:

- Could you tell me a bit more about that?
- What do you mean by that?
- Why did you do it that way?
- Could you explain that further?
- Is there anything else you would like to say?

These unplanned, follow up probes constituted the unstructured part of a phenomenographic interview. Apart from keeping the interview focussed, the purpose of these probes was to:

- encourage participants to reveal as much as possible about the examples they gave about experiencing PLOE (Bowden, 2005)
- explore contradictions and seek clarification (Green, 2005)
- and/or to check the meaning of words or phrases participants used (Akerlind, 2005c)
- Whatever the reason, it was my decision as to which comment to probe and, in doing so, I had to be careful not introduce new information into the conversation (Akerlind, 2005c).

These unplanned, follow up probes often play a more significant role in revealing meaning than planned questions (Akerlind, 2005c). They also play an important role in dealing with inconsistent and/or unclear information during an interview (Barnacle, 2005). This is an important methodological aspect of phenomenography because participants are interviewed only once, and researchers do not engage in member checking (Green 2005). Instead of returning interview transcripts to teachers, for them to check and confirm what they said during the interview, teachers' reflections were clarified during the data collection phase. Follow up interviews and member checking would generate new data, at a different time, when teachers' perspectives may have changed (Bowden, 2005; Harris, 2008). Probing for meaning stopped when participant teachers began to repeat themselves, or found it difficult to elaborate further (Akerlind, 2005b). In this study, interviews typically took 30-60 minutes to reach this point. To avoid any influence on the interview process, the analysis of data did not commence until all of the interviews were conducted (Bowden, 2005; Green, 2005). Unlike other forms of qualitative inquiry, findings that emerge from the analysis of data are not needed to make decisions about the collection of additional data (Green, 2005).

4.1.4. Phase 3: Post-interview Data Analysis

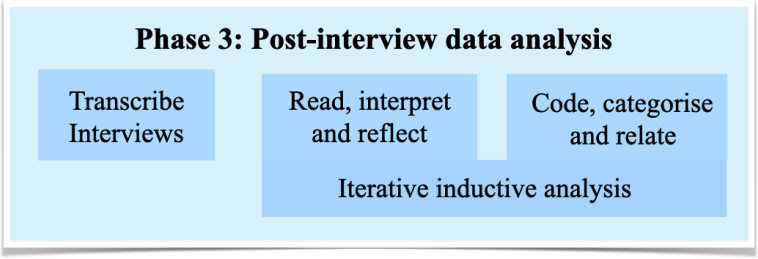
The process of post-interview data analysis occurred through Phase 3 of the research methods sequence, and consists of three parts:

- Transcribe the interviews
- Read, interpret and reflect on the interview transcripts
- Code the interview data into categories of description, and find the structural relationships between the categories

Each of these three parts are discussed in the following sections. Figure 4.5 below shows how these three parts sit within Phase 3 of the research methods sequence.

Figure 4.5

A representation of the Three Parts of Phase 3 of the Research Methods Sequence



My ethical obligations for working with participant data were met by: using pseudonyms to protect teacher identity; using identity codes to safeguard data confidentiality; and aggregating data and editing quotes to remove identifying information.

Step 1 - Transcribe Interviews. Typically, phenomenographic interviews are audio recorded then transcribed verbatim (Green, 2005; Green & Bowden, 2009; Marton, 1986). I uploaded the audio files from 16 usable interviews into NVivo (a software program for qualitative data analysis), then transcribed the interviews to yield over 200 pages of raw interview data. These pages contained the reflections teachers give of their experiences of PLOE during the interview, and formed the focus of data analysis (Akerlind, 2005d; Marton, 1986). In the following section I describe how I reduced so many pages of interview data to a small number of categories, and the relationships between them.

Step 2 - Read, Interpret and Reflect. At this stage of the analytical process, I familiarised myself with the data through reading the transcripts (Green, 2005; Prosser, 2000), to identify the different ways teachers experienced the same phenomenon (Dall'Alba, 2000). While reading the transcripts I used the memo feature in NVivo to record budding ideas, hunches, and reflections. I looked for expressions of what PLOE meant to teachers (Akerlind et al., 2005), aspects of this phenomenon they were aware of (Marton & Booth, 1997), and answers they gave to probing questions (Reed, 2006). I was particularly interested in the relevant parts of an interview transcript where teachers reflected on their experience of PLOE, referred to as the "meaning units of experience" (Reed, 2006, p. 9). The analytical process in phenomenography is an iterative one, that moves between a search for meaning, and a search for structure. For the purpose of describing this process, I begin with a focus on meaning.

A Search for Meaning. When deciding how to conduct this analytical process, I wrestled with the question of how much of any one transcript to analyse at once. One option was to analyse the meaning of selected quotes, within the context of the whole transcript, and never separate them from their context (Akerlind et al., 2005). However, using the context of the whole interview could place too much focus on the individual teacher (Akerlind, 2005d). My focus was on variation across a group of teachers, rather than the detailed nuances of individual experience (Tight, 2016). Also, within a whole transcript an individual teacher may describe more than one way of experiencing the phenomenon (Barnacle, 2005). This complicates matters if attempts are made to classify a whole transcript according to only one way of experiencing a phenomenon.

I chose the other option, which was to remove selected quotes from all of the transcripts and place them in a decontextualised "pool of meanings" for analysis (Marton, 1986, p. 43). I then classified quotes rather than whole transcripts (Reed, 2006). This meant interpreting a quote within two contexts, the whole original interview it was removed from, and the pool of meanings it was placed into (Marton, 1986). NVivo was initially helpful in this regard because selected quotes were placed into a pool of meanings, yet remain linked to the whole, original transcript. This made it easier to move between both contexts and overcome the problem of de-contextualisation of quotes from the original transcripts. It also helped to facilitate the shift to "collective meaning" (Akerlind et al., 2005, p. 92). However, I found NVivo could only go so far. This process is discussed in the next phase. Choosing this approach to data analysis meant there were less data to manage, because quotes were removed from the interview transcripts, and irrelevant data were left behind (Reed, 2006). In total, some 400 meaning units were identified.

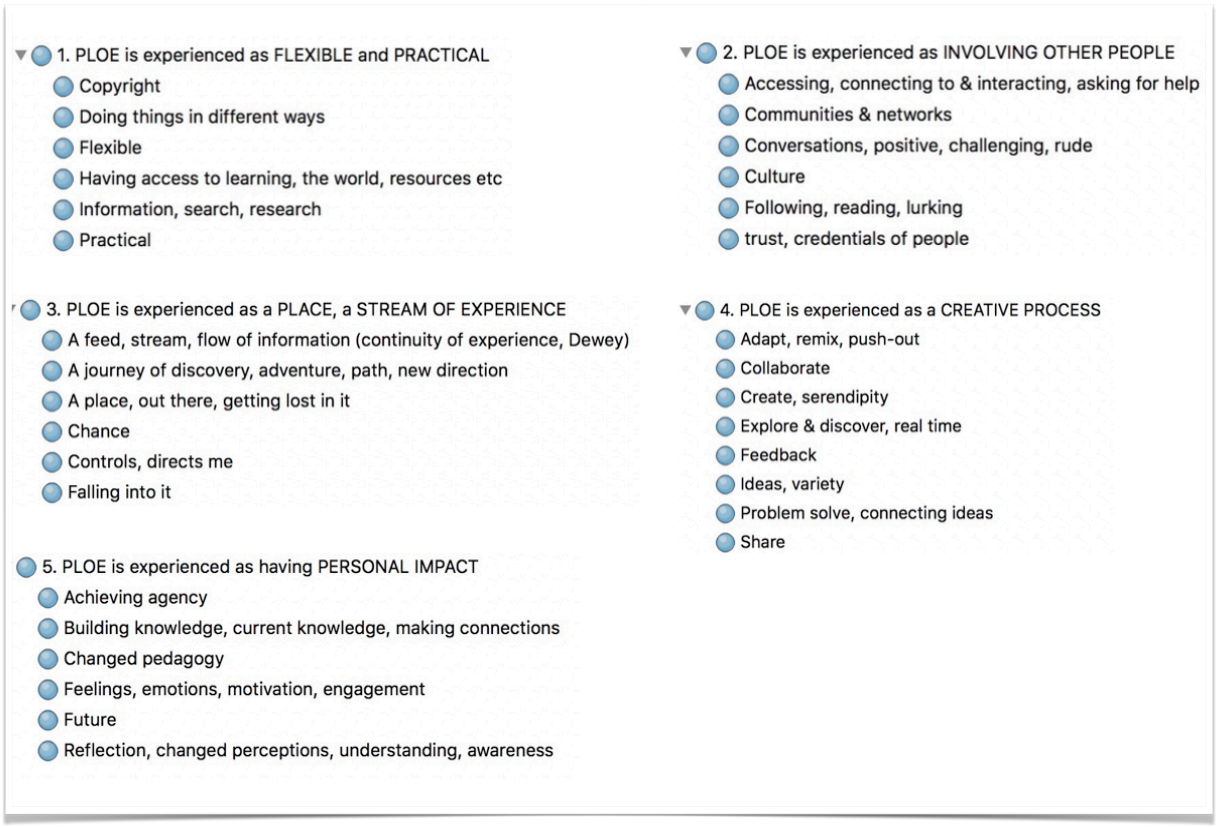
Step 3 - Code, Categorise and Relate. This final part of Phase 3 is an iterative process of inductive analysis, involving immersion in the data, coding, categorising, relating, as well as re-reading, interpreting, and reflecting. Following transcription of the interviews and immersion in the text through reading the transcripts, I needed to make an important, practical decision regarding how many interviews to analyse at once. I had to choose whether to analyse all 16 interview transcripts as a set (Trigwell, 2000), or take a more practical approach and begin with a small number of interview transcripts prior to attempting the full set (Akerlind et al., 2005). Initially, I attempted the former approach. I began by interpreting

the meaning of the quotes/meaning units. At times I found the meaning of a quote in the quote itself (Marton, 1986), in which case I used the exact words expressed by participants (Akerlind et al., 2005; Cherry, 2005). However, even though it its acceptable to interpret the meaning implied by the expressed words, it is not acceptable for inferences to be made regarding what else participants might have said (Akerlind et al., 2005). While interpreting the meaning of the quotes, I began to compare these meanings, noting their similarities and differences (Akerlind, 2005d; Marton, 1986; Sin, 2010).

The next step in this interpretive work was to constitute the categories of description, where I began to group the quotes based on the similarity and difference of their meaning (Marton, 1986; Trigwell, 2000). These categories were not determined in advance (Barnacle, 2005; Bowden, 2000a), nor were they formed from my experience, conceptions, ideas or constructs (Barnacle, 2005). They emerged from the data (Dall'Alba, 2000; Walsh, 2000) through a comparative and iterative analytic process (Akerlind et al., 2005; Limberg, 2008). This process involved reading and re-reading of transcripts, identifying patterns of similarity and difference in the pool of meanings, and modifying the emerging, draft categories of description. Even though I was overwhelmed with the data in my attempt to analyse all 16 interview transcripts as a set, I did manage to reduce 400 meaning units to 32 codes and then five draft categories, as shown in Figure 4.6. below.

Figure 4.6

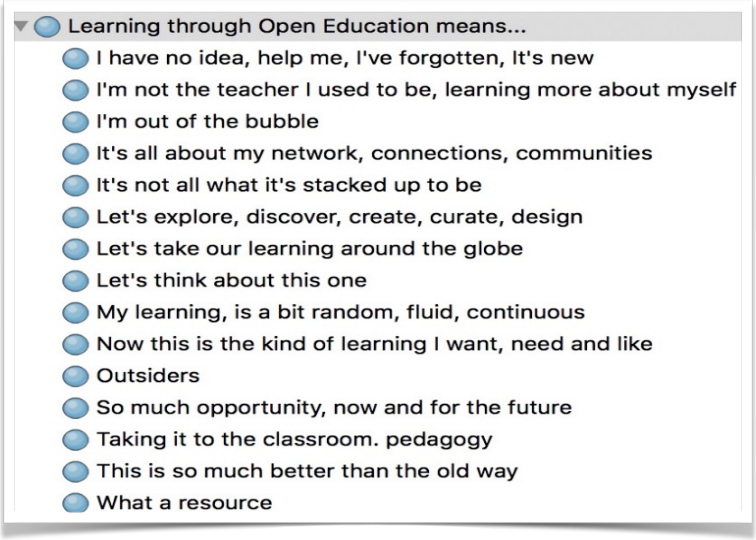
Five Draft Categories Yielded from my Preliminary Analysis



I was challenged by this interpretive work, and found myself focusing too much on individual detail instead of meaning. I also distilled codes into my own abstract language, inserting too much of my abstract thinking into the processes of coding and categorising. It was difficult not to let my experience and ideas influence the formation of categories. Categories should emerge from the data based on similarity and difference of the meaning found in quotes. With the advice of one of my supervisors I attempted the more practical approach of beginning with a small number of interview transcripts (Akerlind et al., 2005). I narrowed my focus down to the meaning units in the transcripts of seven teachers. This time I used the teachers' own language for codes, and sought meaning through the eyes of the teachers, not in my own abstract way. This empathetic mode for coding meaning units immediately made the process much easier. This application of the "second-order perspective", where the world is described as it is experienced by a participant, is essential to phenomenography and yielded the 15 codes shown in Figure 4.7 below (Barnard et al., 1999; Marton, 1981, p. 177).

Figure 4.7

15 Codes Yielded from my Second Attempt at Data Analysis



I attempted to reduce these 15 codes, but these felt too 'constructed' and artificial. It was a struggle to see patterns with NVivo, so moved out of this software and reflected: 'All I see is codes, not teachers describing their experiences to me. It's too abstract too soon. Even though all codes link back to the original interviews, the teacher speaking to me is hidden behind the code, the words I choose to represent their experience'.

In my next attempt I went back to the meaning units in transcripts of five teachers. This is because I needed to see more clearly the analytical step of shifting focus from the meanings expressed by individual teachers, to the collective meanings expressed across the group of participant teachers (Akerlind et al., 2005). I found this process the most difficult. This time I colour-coded the teachers' meaning units, to see them as 'individuals', then placed coloured sentences into categories, then codes, according to their similarities and differences. I then removed the colour. This symbolic removal of colour signified moving from the individual to collective perspective, helping to overcome my analytical challenges. During this process I remained mindful of the need to keep the context of the original interview in mind (Prosser, 2000). As Marton (1986) once claimed, "interpretation is an interactive procedure which reverberates between these two contexts" (p. 43). Keeping focus on these two contexts is not easy and I found myself 'reverberating' a great deal. Nevertheless, it yielded 22 codes that fell under the 5 draft categories shown in Table 4.8.

Table 4.8

The 22 Codes in 5 Draft Categories Yielded from Focusing on 5 Teachers

Professional Autonomy	Change	Social	Creativity cycle	Consequence
Access	In thinking	Network	Exploring, searching and discovery	Opportunity
Approach to learning	In teaching and doing	Negative aspects, be aware	Information and resources	Future
	In myself	Following	Serendipity and randomness	
	Emotional	Conversations	Reflection	
	Benefits	Using		
	Skills	Sharing		
	Opportunity	People		

Analysis of the remaining 11 interviews was completed through an iterative process of testing them against the draft categories in Table 4.8 and making adjustments to the categories when differences emerged. That is, I assigned the meaning units identified in the remaining 11 interviews to these five draft categories. This resulted in further adjustments to the contents, number and title of each category. My conclusion from this lengthy process was that I agreed with Akerlind et al. (2005), that it is far better to analyse a small set of interviews at once.

Throughout this iterative process I re-read the individual transcripts to search for new information that supported, or ran counter to, the draft categories. I looked for missing information, alternative meanings, and/or contradictory evidence (Green, 2005). When new information was found, new patterns of similarity and difference were identified, quotes were arranged and re-arranged, and the categories were adjusted. Finally, this process of adjustment and re-adjustment stabilised, and the "core meanings" of each category were described (Marton, 1986, p. 43). I reached this point when re-reading a transcript no longer revealed new information (Bowden, 2005). Ultimately, six categories emerged, where the title of each category represents its 'core' meaning. They are shown in Table 4.9.

Table 4.9

A Summary of the Meaning of the Final Categories of Description

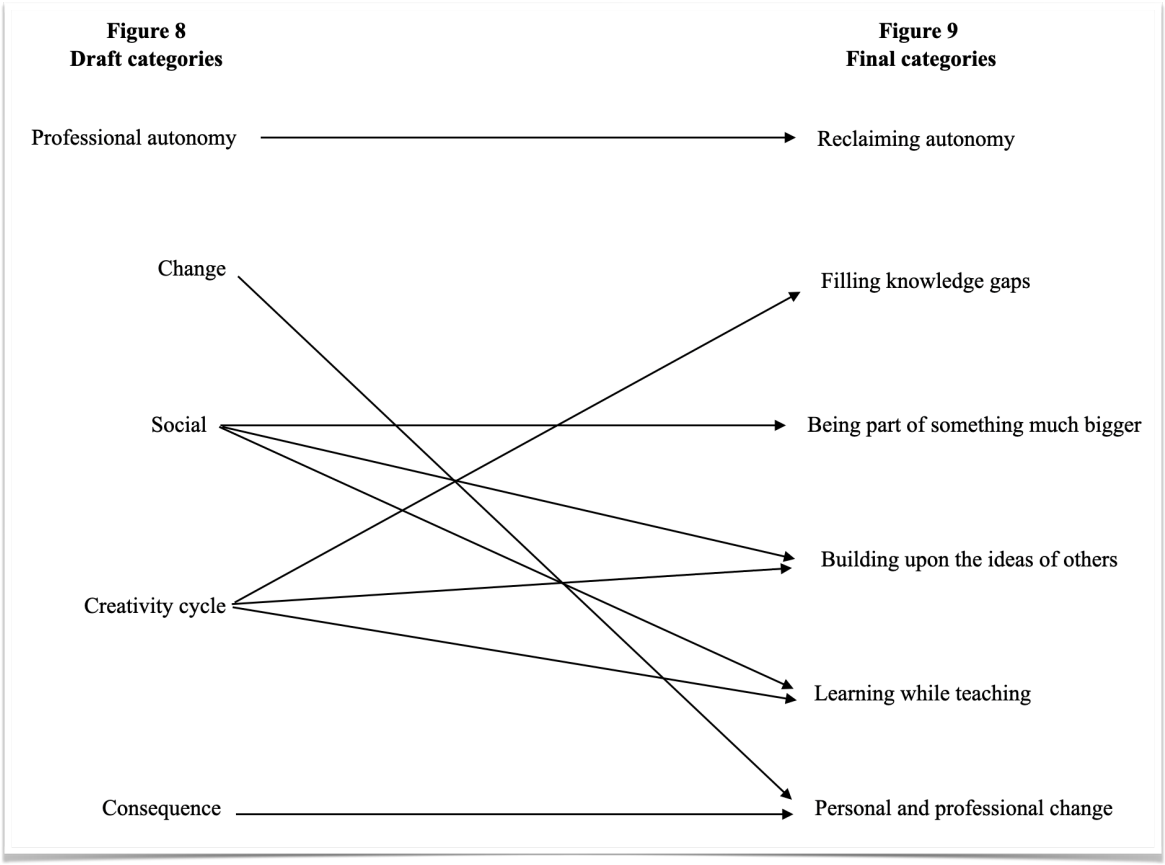
	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6
Title	Reclaiming Autonomy	Filling knowledge gaps	Being part of something much bigger	Building upon the ideas of others	Learning while teaching	Personal and professional change
Meaning	Having choice and independence over one's professional learning	Becoming more knowledgeable about STEM education	Extending one's own professional learning experiences beyond what is offered in the workplace	Repurposing the ideas and resources of others to suit different contexts	Learning with, from, for and about students in the formal context of a classroom	Learning about oneself in terms of change as people, learners and teachers

A comparison of Table 4.9 with Table 4.8 shows that, while some categories are similar, albeit with more descriptive titles, the extra category is 'Learning while teaching'. Adjustments made to contents, number and title are as follows. Firstly, (referring to the Figure 4.10 below), the draft categories titled 'Change' and 'Consequence' were combined to form 'Personal and professional change'. In both instances, the experience of PLOE represents teachers gaining more understanding of themselves, becoming more aware of changes in themselves and the consequences of their decision making and choices. Secondly, three distinctly different categories emerged from the draft category 'Social'. 'Being part of something much bigger' refers to the interactive and social experiences of being in different places, with different people, on the open Web. This differs to 'Building on the ideas of others' which describes more than just social interactions. It refers to people working with each other's knowledge and ideas in creative ways. 'Learning while teaching' is different again, making explicit reference to PLOE occurring in the social, classroom context, with students and people on the open Web. Finally, with its focus on information, the draft category 'Creativity cycle' was distributed over one new, and two existing categories. 'Filling knowledge gaps' emerged as a uniquely teacher-centred, non-social, experience of PLOE where teachers search for, manage and use information to become more knowledgable about STEM education. As mentioned above, 'Building on the ideas of others' is a creative experience of PLOE but it differs to 'Filling knowledge gaps' due to it being social in nature.

'Learning while teaching' is also a creative and social experience of PLOE, but it occurs explicitly in the classroom context.

Figure 4.10

Adjustments Made to the Draft Categories



This lengthy process actually took more than the four iterations reported here. I have only reported those that involved clear changes in my thinking that helped me move forward to constitute the final categories of description. The next challenge was to establish how the categories were different from, and similar to, each other (Akerlind et al., 2005; Marton & Booth, 1997).

A Search for Structure. The structure of awareness, the theoretical model underpinning the concept of structure as used in this chapter, is elaborated in the previous chapter. To reiterate, the structure of awareness refers to aspects of the phenomenon of PLOE teachers are aware of and focus on simultaneously (Marton & Booth, 1997). Structure also refers to the relationships between the categories of description (Stenfors-Hayes et al., 2013). As discussed earlier, in this chapter my search for structure alternated with the comparative and iterative search for meaning described in the previous section. This is because the referential (meaning) and structural components of individuals' relationships with a phenomenon are "dialectically intertwined" (Marton & Booth, 1997, p. 87). When beginning the search for structure I looked for the overall focus of each category. In other words, what is focused on when a particular meaning is ascribed to each experience of PLOE? In Table 4.11 below, the referential (meaning) information shown previously in Table 4.9 is retained, but the structural information related to the overall focus of each category is added.

Table 4.11

Referential and Structural Components of the Six Categories of Description

	Category 1	**Category 2**	**Category 3**	**Category 4**	**Category 5**	**Category 6**
Title	Reclaiming Autonomy	Filling knowledge gaps	Being part of something much bigger	Building on the ideas of others	Learning while teaching	Personal and professional change
Meaning	Having choice and independence over one's professional learning	Building STEM content and pedagogical knowledge	Extending one's own professional learning experiences beyond what is offered in the workplace	Adapting and creating new ideas and resources to suit specific contexts	Learning with, from, for and about students in the formal context of a classroom	Learning about oneself in terms of change as people, learners and teachers
Structural focus	Opportunity for and flexibility of learning	Finding useful information and resources	The interactive, social digital learning environment	Repurposing/ transforming information and ideas	Pedagogical applications – students and teachers learning together	Reflecting on what brings about personal and professional change

Having interpreted the overall structural focus of each category, I took a closer look at the structural features and aspects of experience that constitute this focus.

Phenomenographers assume that a certain way of experiencing a phenomenon is associated with the few, particular features an individual is simultaneously aware of at a certain moment in time (Akerlind, 2008; Marton & Booth, 1997). For example, during an interview a teacher may focus, and reflect on, certain structural features of the experience of PLOE that are important to them, such as searching for information about how to teach chemistry; having a conversation with someone about coding; and repurposing a science test that was shared on social media. To make the analytical shift from an individual, to the collective level of experience, the process of finding the structural features of each category begins by removing the nuance of individual experience. Thus, the structural features listed above become 'searching', 'communicating' and 'repurposing'. Following the comparative and iterative process of data analysis described in this chapter, a range of different structural features were identified in the focus of each category. These features are elaborated in the next chapter in which the findings are presented. The final analytic step was to search for the structural relationships between the categories.

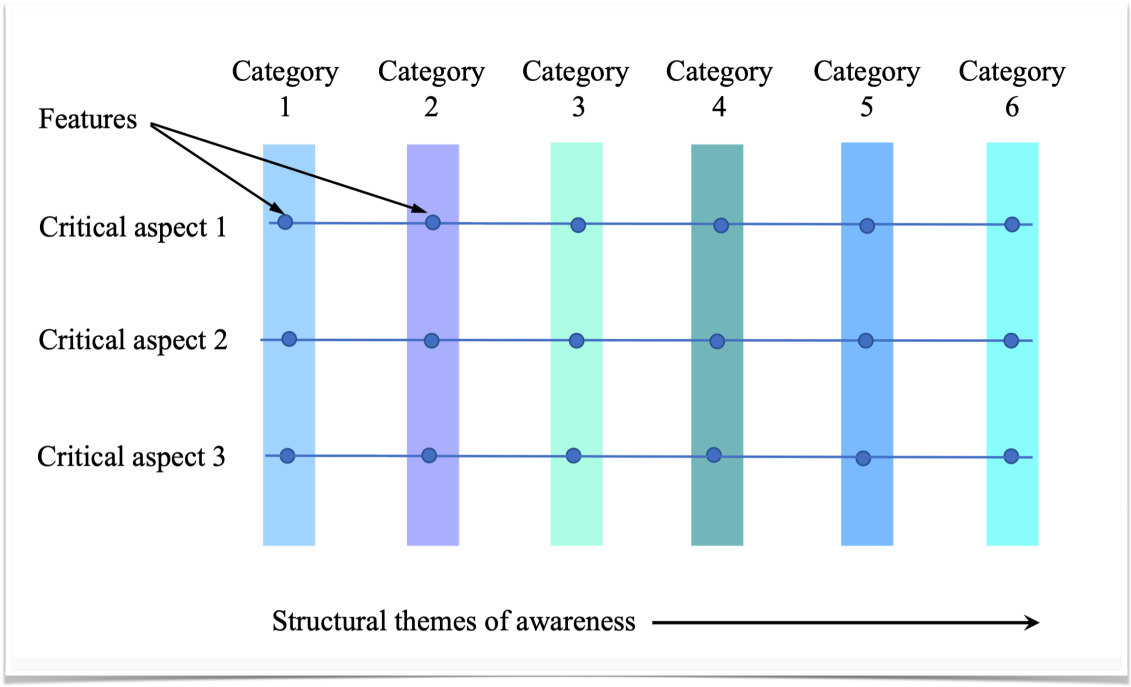
The six categories in Table 4.11 that describe the different ways PLOE is experienced by a group of teachers "are not just random individual subjective imaginings" as Pang and Ki (2016, p. 325) so eloquently stated. They represent different experiences of the same phenomenon, and are assumed to be structurally and logically related at the collective level across a group of participants (Marton & Booth, 1997; Pang & Ki, 2016; Reed, 2006). The example introduced in the previous section will be used to illustrate a relationship. Three structural features of the experience of PLOE were identified and reduced to the words 'searching', 'communicating', and 'repurposing'. As a group, they are the 'practices' that teachers engage in while experiencing PLOE (what they do to learn). The 'practices' of teachers is an example of an 'aspect' that relates, yet differentiates, the different experiences of PLOE described in the 6 categories. It relates the categories because it is found in every category, but differentiates the categories because the 'practices' of teachers have different features in each category. In other words, its features vary across the categories. Such an aspect is referred to as a "critical aspect" in the literature, because it helps to account for the

"critical differences" between the different ways a phenomenon is experienced (Pang & Ki, 2016, p. 323).

The critical aspect of 'practices', and its corresponding features in each category, constitute a structural theme, or theme of "expanding awareness" that runs through and connects Categories 1 to 6 (Akerlind, 2005a, p. 16; Reed, 2006). Figure 4.12 shows how critical aspects, and their corresponding features in each category, form structural themes of awareness running as threads across the categories of description.

Figure 4.12

The Relationships Between the Categories of Description, Features, Critical Aspects and Structural Themes of Awareness



When teachers were interviewed about their experiences of PLOE, many aspects of this phenomenon were described. However, the following five 'critical aspects' were selected by the researcher as being most relevant to the research question, constituting the most critical and educationally significant for the developmental purpose of the application of these findings:

1. Learning
    - Whose learning is in focus?
    - What is learning experienced as?
2. Learning practices
3. Openness
    - The open Web as a learning context
    - The culture of openness
4. Learning problems and barriers
5. Validation of learning

Finally, the features, critical aspects and structural themes of awareness are seen as constituting the outcome space, described by Marton and Booth (1997) as "the complex of categories of description comprising distinct groupings of aspects of the phenomenon and the relationships between them" (p.122). Within the outcome space the categories of description are arranged in a "hierarchy of inclusiveness" (Akerlind, 2008, p. 635) because some categories are seen as more complex or inclusive than others (Pang & Ki, 2016). The outcome space is presented in the next chapter, along with a detailed discussion of the nature of the relationships between the categories of description.

4.3. The Role of the Researcher

The researcher is the final component of a phenomenographic study (Bowden, 2005). As outlined in Chapter 1 my interest in conducting this research emerged from previous experience as a secondary teacher of STEM subject areas, and my current experience of learning through Open Education. These interests influenced my decision to conduct research into the experience of PLOE from the perspective of Australian teachers of STEM subject areas. My interests also influenced the purpose of this study, which is to "inform and improve" the professional learning opportunities offered to Australian teachers of STEM

subjects (Green & Bowden, 2009, p. 57). From the very beginning my intention was for the findings of this research to be applied in this area.

As the researcher I didn't stand outside the context of this study like Yanow (2006) described as being "removed, distant—"objective"—in the mode of the white-coated lab experimentalist observing rats in a maze or cells in a petri dish" (p. 81). Quite the opposite, I recognise that I was part of the world I studied, bringing my "own subjectivity to the research table" (Cousin, 2010, p. 9). I am aware that my personality, values, beliefs, assumptions and experiences inform how I see the world, and had the potential to impact on the process and findings of this research (Yanow, 2006). I see this as a strength and a source of inspiration, not a limitation, and acknowledge the importance of using strategies to manage, not eliminate, the presence of self. In fact I agree with Cousin's (2010) reflection that "The self is not some kind of virus which contaminates the research. On the contrary, the self is the research tool, and thus intimately connected to the methods we deploy" (p. 10). In this chapter I described the methods used to study the relationship between teachers and PLOE, also referred to as experience of PLOE. Embedded in the descriptions are the strategies used to minimise the influence of myself, the researcher, on this focus.

As the sole researcher conducting a phenomenographic study I made all of the decisions to: design it; inform and recruit participant teachers; develop an interview guide; conduct and transcribe interviews; and analyse and interpret data. Steps were undertaken to minimise the influence of my relationship to PLOE and to the participants, for example, by: making sure that when interviewed, the participants and myself discussed the same phenomenon; not offering my perspective about PLOE during the interview or making judgemental comments regarding the experiences teachers shared with me. Predetermined categories based on my understanding of PLOE were not used during the analysis of data and the only evidence used to constitute the categories of description was found in the interview transcripts. As I explained in Chapter 3, I took a reflexive and ethical approach towards all aspects of this study to enhance its quality and trustworthiness.

4.3. Chapter Summary

Phenomenography was the methodology described in this and the previous chapter. The purpose of this chapter was to make explicit to my readers how this phenomenographic study was conducted. It described the methods used, across three phases, to explore and describe variation in the experience of PLOE. The description of each phase dovetailed with descriptions of the five components of this phenomenographic study: the phenomenon of PLOE, the group of Australian teachers of STEM subjects who participated in this study, the interview as a way to communicate experience, the process of analysing data for meaning and structure, and the researcher. It was found that variation in the experience of PLOE can be described through six categories of description and five critical aspects. Chapter 5 follows with a presentation of the findings, in which the categories are described individually, sequentially, and in detail. The findings will also be structured into an outcome space is represented in diagrammatic form.

CHAPTER 5. FINDINGS

In the last chapter the research methods were presented in terms of a three phase sequence of data collection and analysis. This chapter reports the findings that represent answers to the research sub-questions one and two. To reiterate, the main research question is: What are the qualitatively different ways that professional learning through Open Education is experienced by Australian teachers involved in STEM education? The two sub-questions are:

RQ1: What are the different meanings Australian teachers involved in STEM education attribute to the experience of PLOE?

RQ2: What aspects of PLOE are critical to the different ways this phenomenon is experienced by Australian teachers involved in STEM education?

I begin by presenting the six qualitatively different ways of experiencing PLOE evident in the data, as six categories of description in a phenomenographic outcome space. The experience of PLOE in each category is then described in detail in terms of both meaning (referential component) and the structural aspects (the structure of awareness) of this way of experiencing PLOE, supported with selected quotes from the interview transcripts which reflect this experience. Following this, the structural relationships between the experiences of PLOE in the six categories are described in terms of critical aspects, features, and themes of awareness that run as threads across the categories. The unique structure of the outcome space is then presented and explained in the context of answering RQ1 and RQ2. The chapter ends with a summary of the research findings. Chapter 6 will address how these findings contribute to theorizing about STEM teachers' professional learning through Open Education and how this new knowledge can be used to design meaningful professional learning experiences for Australian teachers involved in STEM education.

5.1. Categories of Description

PLOE was found to be experienced by the group of teachers in six qualitatively different ways. Using the words of participant teachers to capture this meaning, PLOE is variously experienced as:

1. Reclaiming autonomy
2. Filling knowledge gaps
3. Being part of something much bigger
4. Building on the ideas of others
5. Learning while teaching
6. Personal and professional change

Variation in the meaning of experience reflected in the above six categories (the referential component) is due to the specific combination of structural features of PLOE that teachers were aware of, and focussed on, simultaneously (that is, the structure of awareness). During the analysis of data, outlined in the previous chapter, these structural features were grouped into five critical aspects of awareness. The critical aspects described in each category are:

1. Learning
    - Whose learning is in focus?
    - What is learning experienced as?
2. Learning practices
    - What 'practices' do teachers engage in while experiencing PLOE (what they do to learn)?
3. Openness
    - How is the open Web described as a learning context?
    - How is the culture of openness experienced?
4. Learning problems and barriers
    - What are the problems and barriers associated with the experience of PLOE (described as technical and/or personal)?
5. Validation of learning
    - Who validates (approves, confirms, endorses, justifies, verifies, authenticates) the experience of learning?

What follows are detailed descriptions of the experience of professional learning in Categories 1 to 6 that include:

A. A statement elaborating the meaning of the experience of PLOE (referential component) reflected in the category's title, along with selected quotes from interview transcripts as supporting evidence of this distinct way of experiencing PLOE.

B. The overall focus of the awareness of PLOE reflected in each category.

C. How the experience of PLOE in each category is delimited from its context (that is, how PLOE is differentiated from other experiences of professional learning).

D. The critical aspects of awareness in each category, with reference to specific features of PLOE considered important from the perspective of teachers (see 1-5 above)

5.1.1. Category 1: The Experience of PLOE as Teachers Reclaiming Autonomy

In this category, PLOE is experienced as reclaiming autonomy over one's own professional learning, as articulated in these quotes:

> *I think, sometimes our school, for example, will say 'this is your goal for this year' and I say 'really? … I said what I wanted to do was this, but now, thanks for taking away my autonomy and my ability to think and be creative in my own way! So I think that one thing is that we need to give back teachers their autonomy to participate in the professional learning that they want. (Teacher 7)*

> *I find it easier for me to get the specific thing that I want, online, rather than rely on and hope that the school will be going in the direction that I want to be going in and have the budget to allow me or others to engage with it. (Teacher 2)*

Having choice and independence in one's own professional learning is seen as a meaningful way to learn about STEM education for a number of reasons. Some teachers: seek involvement in the direction their professional learning takes; want to keep motivated in their profession; feel too controlled, misunderstood and ignored by school administrators; are unsupported when pedagogical change occurs in their schools; and may have limited access to professional learning, particularly in rural and isolated areas. Thus, the focus of awareness in this category is the opportunity for, and flexibility of, their own learning.

The experience of PLOE in Category 1 is differentiated from other professional learning experiences because it is managed by teachers themselves. It is unregulated, and not mandated by school administrators and/or teacher registration authorities. It is a bottom-up, in contrast to a top down, regulated approach to professional learning, and does not include schools providing and paying for professional learning.

Nonetheless, learning is still experienced as being validated by an external authority:

> *We have to do some online learning that's directed by the school, and that's mostly with the Department of Education so like, you know, log onto this 30 slide website about anaphylaxis, that stuff. So that's self-directed by me but then the professional development that I do, that I choose to do personally, there's nobody there saying 'oh why don't you do this, or why don't you do that. (Teacher 7)*

The critical aspects that constitute the focus of awareness in this category are: Learning, Learning Practices, Openness, Learning Problems and Barriers, and Validation of Learning; are now described. 'Learning' is an individual experience where only the teachers' learning is in focus:

> *I needed to find other alternatives, and what I was being offered in the system I was working in, for me, wasn't fulfilling my wants and needs. (Teacher 12)*

Learning is experienced as flexible because teachers have the opportunity to choose what to learn; the time and length of the learning episode; the computing devices to access learning opportunities on the open Web; and the physical location to learn (for example, from home or at school, while travelling or in a cafe):

> *I think that learning on the open Web really differs from the school based approach in that I can choose what it is I'd like to learn and it directly relates to my subject area. (Teacher 7)*

> *I can do it in my own time, in my own space if I'm at home and feeling the urge I can connect at anytime. (Teacher 5)*

Learning is also experienced as self-directed. In this sense, autonomy refers to teachers directing their own learning, due to their unique motivations, as opposed to the motivations of their employers:

> *I think when you participate or you can have a say over the direction you want your learning to take, it's just much more powerful, far more interesting and engaging and you'll spend much more time on it, has more impact on what you retain and what you'll go ahead and explore. (Teacher 1)*

The 'Learning Practices' of teachers in this category are interpreted as the decisions teachers make about their own learning. In this sense, autonomy refers to teachers making decisions about what, when, where, how and why they want to learn on the open Web, according to their own needs, wants and interests. The critical aspect of 'Openness', in terms of 'The open Web' as a learning context, is understood by teachers in this category as a 'thing' to access:

> *The Web, it's an open thing, it's there and it's free access, if you've got a connection then great, go for it. It just is open, I guess. (Teacher 2)*

'The culture of openness' reflects awareness of accessibility in terms of 'open' to all, at no cost, and with no sign-up or membership required:

> *I guess open Web means open to all, accessible whether its cost wise or technology wise and I guess time wise as well. (Teacher 6)*

> *The open Web would be things that you could access without having to sign up to be a member or pay to be a part of. (Teacher 10)*

There is no awareness of Open Educational Resources (OER) or open licensing (Creative Commons, CC). The learning problems and barriers associated with the experience of PLOE in Category 1 are technical. Teachers need a reliable internet connection to access the

internet. However, problems exist for teachers who live and teach in areas where there are issues with internet access, poor connectivity and slow internet speeds:

> *You know there's the obvious physical or logistical, like sometimes we don't have internet access in the country and it's slow, you know, those kinds of things. (Teacher 5)*

Finally, there is awareness that learning in this category can be externally and officially validated by teacher registration authorities, as evidence of professional learning:

> *Yes, where you have the professional learning requirements where you have to write down all the professional learning minutes you have done, as part of you registration, not that I would always record that down, but at least I could record that if I choose to. (Teacher 6)*

Table 5.1 below gives a summary of the experience of PLOE described in Category 1.

Table 5.1

A Summary of the Meaning and Structure of Category 1

Category 1	
A. Meaning	Reclaiming autonomy
Representative quote	*I think, sometimes our school, for example, will say 'this is your goal for this year' and I say 'really? … I said what I wanted to do was this, but now, thanks for taking away my autonomy and my ability to think and be creative in my own way!. So I think that one thing is that we need to give back teachers their autonomy to participate in the professional learning that they want. (Teacher 7)*
B. Focus of awareness	Opportunity for and flexibility of learning
C. How PLOE is differentiated from other professional learning experiences	Unregulated; not mandated
D. Critical aspects of awareness	
1. Focus of the Learning Experience	
Whose learning is in focus?	Teacher's
What is learning experienced as?	Voluntary, self-directed, flexible, bottom up
2. Learning Practices What 'practices' do teachers engage in while experiencing PLOE (what they do to learn)?	Make decisions over what, when, where, how and why they want to learn.
3. Openness	
How is the open Web described as a learning context?	A thing
How is the culture of openness experienced?	Accessible and open to all, free, no membership; no awareness of OER or CC licensing (accessibility)
4. Learning Problems and Barriers What are the problems associated with the experience of PLOE (described as technical and/or personal)?	Poor internet access, connectivity and speed
5. Validation of Learning Who validates (approves, confirms, endorses, justifies, verifies, authenticates) the experience of learning?	Teacher registration authorities may validate PLOE if provided as evidence of PL. In Category 1, the awareness of how PLOE is validated is still constrained within the regulatory system.

5.1.2. Category 2: The Experience of PLOE as Filling Knowledge Gaps

In Category 2, professional learning through Open Education is experienced as filling knowledge gaps:

> *This year I'm teaching year 12 for the first time and some of the content I may have forgotten or are not familiar with because of course changes. My aim for learning is therefore content, to improve my practice for the students. (Teacher 6)*

> *We don't have to go with the 'I don't know' approach, I guess, anymore. (Teacher 6)*

Through engaging in PLOE, teachers address the limitations of their knowledge about STEM subject areas and their need to learn more about STEM education:

> *...being a primary school teacher you're not necessarily an expert in a curriculum area. You're a generalist teacher. So, I fully admit that my knowledge of some science topics and concepts is fairly limited. (Teacher 12)*

> *I love curriculum and my interest is, like I'm a science teacher so we have to know heaps, and, like, my specialist area is chemistry. But, I don't know, I like logging on and learning stuff having to do with the curriculum that I'm teaching. (Teacher 5)*

Filling in the knowledge gaps is seen as a meaningful way to learn about STEM education for a variety of reasons: teachers may have forgotten information; may not have taught in STEM subject areas for some time and/or may feel out of their depth when teaching unfamiliar content; they may be teaching out of field, are not specialists in STEM subject areas and may have no official training:

> *We don't have to go with the 'I don't know' approach, I guess, anymore. (Teacher 6)*

Some teachers are implementing new pedagogical approaches for STEM education and/or seeking new, interesting, authentic, contemporary, current and global content for their lessons:

> *They want us to start flipping the classroom, that's why I've been looking at the Khan academy and I'm finding them quite good. (Teacher 3)*

> *I feel more that I am up to date with what's going on with the profession, not just nation wide but also world wide. (Teacher 8)*

The focus of awareness in this category is the information (also seen as resources) available on the open Web that teachers access and use to increase their knowledge of STEM education:

> *So for me to find out more about those concepts, for example, science, and even engineering to a certain extent, because I'm not skilled in that area either, I had to go out and find resources on the web that help explain what some science and engineering concepts were actually were because I had no idea. (Teacher 12)*

Thus, Category 2 describes how teachers use information to fill their knowledge gaps about STEM education. This experience is differentiated from other professional learning experiences that are closed, or "firewalled', out of date and standardized:

> *I think even using Fuse which the Victorian Government set up for their interactive and digital resources, I don't find those particular sites very user friendly. (Teacher 10)*

> *I mean if you've got to pay for something I don't think that that's definitely not considered as open but because you've got to have an outlay there. (Teacher 12)*

It [Scootle] has a role to play but it's just on that juncture between work which is copyright and work that's been fire-walled and perhaps the more open work where you have the various lists, the free spaces like Twitter, and some of the Facebook communities. (Teacher 14)

At the moment I really think whether it's STEM or anything I think that the only way to stay current is to be online, unfortunately there's no other way so that way you are most up to date and most current and most able to apply what's happening and see what's happening elsewhere as well. (Teacher 16)

With reference to each of the five critical aspects, 'Learning' is an individual experience where only the teachers' learning is in focus. Learning is experienced as occurring in small, convenient amounts, in an ad hoc way, to top up what teachers know, in bite-sized amounts. Learning happens when teachers deliberately search for information to meet their needs, or information may serendipitously come to a teacher's attention, simply by them being on the open Web, and resonate with a need they have. It is also described as being as a convenient and personal way to learn by teachers who are time poor, and who seek to 'top up' their knowledge, learn 'bit by bit' and learn 'right now':

... it's very organic and very ad hoc. It's what I need to know now or if I happen to be online and see something I'm interested in then I will go through and research it. (Teacher 1)

...it's whatever takes your fancy in that moment and on that day, making it very personalised. (Teacher 16)

The benefit of Twitter is that it's piecemeal. Like everyone else you feel time poor, you feel stressed, you feel like you're inundated with stuff, and reading more than the first chapter of a book seems psychologically daunting. Whereas twitter is a little blip, blip, blip and you can just OK I've read something and it just topped me up. So I've kept my levels up without feeling that I've lost a lot of time or I've got to immerse myself. (Teacher 16)

The 'Learning Practices' of teachers described in Category 2 are related to accessing, searching for, finding, managing, archiving and using information. Information in the form of text, audio and video is searched for then 'pulled in' and managed through filtering, bookmarking, aggregating, curating and archiving:

There's some fantastic stuff out there which you can sort of pull in off the open Web, you can pull in and use for your own materials, but, like I said, I use some of those aggregating apps or sites that presents the information like a magazine. (Teacher 4)

In Category 2, 'Openness', in terms of 'The open Web' as a learning context, is experienced by teachers as a space, or 'place' to visit, to search in, that has 'things' to search for and 'pull in':

I have found it a wonderful place to build my content knowledge about concepts related to topics. (Teacher 12)

The Web went from, you know, a bit more of a hobby or something like that, to this really amazing place where everything is out there and all you've really got to be able to do is look for it. (Teacher 4)

Particular metaphors are used by teachers to express their understanding of the nature of the open web as a 'place' and the relevance of 'things' that one finds there:

> *It's like a big lolly shop isn't it? And some things are like, literally like icing on the cake, aren't they, and other things are really deep and meaningful and sometimes you've got to try the glitzy stuff and realise it actually hasn't got any substance. (Teacher 9)*

However, awareness of a 'culture of openness' is similar to Category 1. With reference to ownership and use of information found on the open Web, the experience is one of just taking and using information. There is now some awareness of copyright legislation, Open Educational Resources (OER) and Creative Commons (CC) licensing. This was not the case in the experience of learning in Category 1:

> *No, we know it (CC) exists, but if I'm absolutely honest, no-one cares, you know, copyright, if they find a picture they'll take it and use it. (Teacher 13)*

In Category 2, awareness of 'Learning Problems and Barriers' expands to include technical problems associated with unreliable websites, poor design of some online courses and the variable quality of resources. From the perspective of teachers, the quality of information they access on the open Web is variable. It may not be relevant and/or verifiable, and may have technical limitations:

> *Sometimes the quality of the resources given to you is constrained by technical issues in terms of size of file and time to download, video quality or whatever, and that's frustrating as well. (Teacher 8)*

Personal problems related to learning first appear in Category 2, in the context of teachers experiencing information overload and losing time. Due to the abundance of information on the open Web, PLOE can be seen as an experience that wastes time and contributes to information overload:

> *Yeah, information overload is another one, sometimes there's so much out there you don't know what to do.(Teacher 12)*

In Category 2, the 'validation of learning' refers to teachers validating the information they find on the open Web. They describe checking, and making judgements about, the origins, authenticity, quality and relevance of information they use for learning:

> *It's about being able to interrogate the information in front of you and decide, you know, is that reasonable? (Teacher 10)*

> *And it does provide a lot of really good information if you can, you've gotta be able to make the judgment about the relevance and where it comes from, it's not all going to be academically referenced. (Teacher 10)*

> *I sort of filter it as I go...keep some, ditch some, yeah...I'm finding pretty much what I want. (Teacher 15)*

Table 5.2 below gives a summary of the experience of PLOE described in Category 2.

Table 5.2

A Summary of the Meaning and Structure of Category 2

Category 2	
A. Meaning	Filling knowledge gaps
Representative quote	*This year I'm teaching year 12 for the first time and some of the content I may have forgotten or are not familiar with because of course changes. My aim for learning is therefore content, to improve my practice for the students. (Teacher 6)*
B. Focus of awareness	Finding useful information and resources
C. How PLOE is differentiated from other professional learning experiences	Open (not closed, firewalled); Current (not out-of-date); Personalised, tailored (not standardised)
D. Critical aspects of awareness	
1. Focus of the Learning Experience	
Whose learning is in focus?	Teacher's
What is learning experienced as?	Deliberate and/or serendipitous, ad hoc, top up, bite-sized
2. Learning Practices What 'practices' do teachers engage in while experiencing PLOE (what they do to learn)?	Access, search, find, manage, archive, use information
3. Openness	
How is the open Web described as a learning context?	A place to visit, to search around in, to pull in information from
How is the culture of openness experienced?	Limited awareness of CC license but no interest/care/use Take and use information (acquisition)
4. Learning Problems and Barriers What are the problems associated with the experience of PLOE (described as technical and/or personal)?	Variable quality of information, resources and websites; information overload, losing/wasting time
5. Validation of Learning Who validates (approves, confirms, endorses, justifies, verifies, authenticates) the experience of learning?	Teachers judge/validate information: its authenticity, quality, relevance, credibility

5.1.3. Category 3: The Experience of PLOE as Being Part of Something Much Bigger

In this category, professional learning through Open Education is experienced by teachers as being part of a much bigger professional learning environment:

> *When you're engaging with colleagues and testing your understanding you're part of something much bigger than just one teacher in a school. I found it hard as the only IT teacher in a school, now I'm part of an IT teaching community, and that's because of the open Web and the kind of way that I'm learning. (Teacher 10)*

> *It's a no-brainer really, otherwise you're just living in four walls. The open Web gives you access to the whole world, it's an absolute no brainer. (Teacher 15)*

Extending one's own professional learning experiences beyond what is offered in the workplace is seen as a meaningful way to learn about STEM education for a variety of reasons, such as: learning from people around the world; overcoming isolation; overcoming the limitations of colleagues and professional learning situations in the schools within which they work:

> *So that was a really quality learning experience for me because I enjoy exploring international perspectives on issues. (Teacher 11)*

> *...when you work by yourself and nobody does the sort of work you do, you do need to be able to throw things out there. (Teacher 9)*

In this category the focus of awareness broadens to include the digital learning environment where teachers interact with information, and people, in different 'places' on the open Web.

The social nature of learning comes to the foreground in this category, and the different places teachers visit on the open Web such as social media sites, blogs, search engines, other websites and platforms:

> *Learning through Open Education allows interaction on the internet, so not just getting information, but providing the affordances to share it or to respond to it in some sort of way. And engaging in doing something on the open Web, to me, means engaging socially with other people. (Teacher 7)*

> *And what I've found in my own explorations of different technologies is that software like Google Earth where it allows you to collect data, keep an open mind, doing other things like that, that for me is really important, and also that it's not designed for school, like, it's designed for people, geologists, whatever…(Teacher 7)*

In Category 3 the experience of PLOE differentiates itself as an expansive form of professional learning that exists beyond the school walls. Knowledge, expertise and resources are not limited to the workplace context:

> *So in a staff meeting I don't have the opportunity to ask too many questions because they just go onto the next bit and piece. Often you listen to someone for an hour and soak it in but you can't interact back and ask your question etc, and tease it out. But, if I can be on the open Web I have the opportunity to put questions there when I want them, when I have the need to ask. And others will satisfy my curiosity and either answer them or put in a different question, etc. (Teacher 1)*

Although the social nature of PLOE emerges in Category 3, the teachers' learning remains in focus. What differentiates Category 3 is that learning is experienced in social ways, through interaction and participation with other people. In this category there is also developing awareness of the networked nature of learning on the open Web, where learning is experienced as networked, connected, communal, and informal.

The Category 3 experience shows awareness of the technical and social layers of the open Web, including Personal Learning Networks (PLNs):

> *I find that if I've got that network and the right search criteria, like certain hashtags or something, I can almost learn immediately. (Teacher 1)*

> *I think in the long run, especially with Facebook and the Facebook groups, it's a more informal method of learning and people are inclined to put up different sorts of things that they might not present if they were in a formal setting, presenting formal professional development. (Teacher 10)*

The 'Learning Practices' of teachers broaden in this category and include: observing, interacting with information and people (share and communicate), in different 'places' on the open Web, and participating in online events. Learning happens when teachers follow, observe, listen to and read about what others are doing; and when they interact with diverse and knowledgeable others on the open Web:

> *Do I learn anything? I think you do, you have a look at what sort of things are topical, the areas that people might be investigating or the ways that, where people might be questioning current practices or whatever. (Teacher 10)*

> *I've had conversations with people from all over the country, primary, secondary, higher ed. I thought you know what, where else can I get that, where else can I have the opportunity to engage with such a diverse range, at any point in time, except for on the open Web. (Teacher 2)*

The learning practices of teachers' learning also includes participation in free, online courses (some of which are referred to as massive open online courses, or MOOCs), and other learning events on the open Web, such as conferences:

> *But the other thing that I've found in terms of professional learning that's been incredibly useful to me is doing free online courses through, I'm doing one with DW at the moment, on formative assessment. (Teacher 8)*

> *The courses that I've taken on the MOOC, for example, they were really good because I never thought of approaching geoscience in that way, in my classroom. (Teacher 7)*

The use of metaphor to describe understanding of the open Web as a learning context broadens in Category 3. It is experienced as more than 'a place to search around in' as described in Category 2. Teachers express a sense of moving around in different places 'out there', on the open Web, such as going on a journey, jumping into, jumping on:

> *I realise that there's quality education in certain places I now tend to go to…but when I was starting on this journey I was probably more just..lets check out what this learning is like. (Teacher 8)*

Metaphors are also used in this category to describe how information is experienced on the open Web, for example, as a 'flow', 'feed', 'stream' or 'trail'. Information is seen as coming from somewhere and going to somewhere else, in other words, a sense of the connected/ networked/communal nature of the open Web comes into focus in Category 3.

This sense of connectedness is also apparent when teachers describe their awareness of connecting to and interacting with people, individually and collectively:

> *My investigation into the STEM resources and setting up the STEM blog which I've done recently… I used the hashtag STEM on Twitter, on Google, on Pinterest just to gather ideas and follow the breadcrumbs. So, for example, with the STEM hashtag on Twitter you come across other STEM teachers and organisations and follow them so that more STEM ideas come up in your feed. (Teacher 5)*

> *I read a lot of blogs, so I like reading blogs and I think the best thing about blogs is the comment streams at the end. You learn as much from a comment stream as you do from the blogs. So that's, you know, the whole part of its the Web doing things differently, that way that, you know, the comment streams, lead you to other things that lead you to other things as much as the individual blog post might. (Teacher 13)*

The social nature of PLOE changes the culture of openness experienced in Category 3, where learning is described as democratic, where people are careful what they post, treat each other equally and respectfully, and are encouraged, supported and affirmed. People are helpful, and seem to have an open attitude for altruistically sharing what works, for the benefit of others (for example, through tweeting and re-tweeting):

> *Learning online is, in many respects, democratic, with some exceptions. Most people who are there are happy to help. (Teacher 11)*

> *The people and the organisations who I follow on that seem to have a very open, kind of attitude 'hey I did this, this really worked well for me, give it a go, have a look at it'. (Teacher 4)*

> *Well, the fact that I could talk to principals and people with 20 to 30 years experience and they treat you like an equal. (Teacher 11)*

I know that personally I wouldn't post anything that could be perceived as controversial or anything like that on any topic because you'd never know whose going to be reading it and how they're going to react in that sphere. (Teacher 2)

There is awareness of a positive, communal, culture associated with learning from, and with, different combinations of people, in different places, on the open Web. However, the culture of professional learning on the open Web is not always experienced in a positive way. The anti-social behaviour of people is also apparent. There are people who troll and bait; conversations can be experienced as threatening, unpleasant and unprofessional. Consequently, some teachers feel nervous about sharing their ideas and prefer to remain anonymous, while others experience the slow development of trust as they get to know each other over time:

Everyone is entitled to their opinion, but trolling and baiting and kind of looking for a fight isn't the twitter that I want to participate in. (Teacher 5)

You know, when you work in a sharing and open culture, you sort of expect, you know, some simple decency. When someone offers you some advice, even if you don't agree with it you can at least be polite about how you respond to that. (Teacher 11)

There's also that element of anonymity, or initially there's that element of anonymity, but obviously that breaks down as you get to know people over time. (Teacher 2)

With respect to awareness of OER and CC licensing, there is a similar degree of awareness as in Category 2. However, an element of culture that emerges in this category is how people treat each other when it comes to respecting the ownership of the work they share on the open Web. For instance, there are people who take and share the work of others, without attribution, and claim it as their own. Consequently, teachers describe the need to be selective with the people they follow and the information they share.

These problems are overcome by muting, unfollowing and validating the authenticity of people by searching the open Web for additional information, such as their background and qualifications:

> *I'm very careful about who I follow, muting and unfollowing reduces what comes through my feed. (Teacher 11)*

In Category 3 the technical problems broaden again, to teachers experiencing compatibility problems with web tools and hardware operating systems. Additionally, the experience of using the open Web to learn through online courses, and with people around the globe, can be problematic when time zones are crossed and websites are blocked. There is awareness of a range of web tools to overcome these problems, such as global time converters and archiving tools for recording missed events:

> *If we want to connect with China, you know, they are blocked from a lot of sites that we would like to use to collaboratively learn. (Teacher 1)*

> *The other side is it's frustrating to have access to experts from across the globe but timing is still and issue. As much as I don't sleep, I still don't like being on a chat forum at 4 o'clock in the morning trying to sound intelligent. (Teacher 8)*

> *If I can't be in real time I can always go back to the Storify or archived events. (Teacher 1)*

As mentioned above, personal problems related to the ugly side of social media come into focus, such as misunderstandings, rudeness, arguments, trolling and baiting. Another personal problem, for some, is the obsessive checking of social media. In Category 3, validation refers to teachers checking the authenticity and credentials of people they follow and communicate with on social media.

Teachers make judgements about the credibility of people and the information they share. Are they who they say they are, is what they say from a credible source?

> *I think the difficulty, especially around social media, is the credentials of people who put things up. It's hard to ensure that the information is solid. (Teacher 10)*

Validation also occurs through teachers recognising and accepting each other in social ways. For example, through liking posts, following each other, sharing and communicating with each other, teachers are validated when they receive feedback, and when their feelings and perspectives are acknowledged and accepted. The social and networked nature of PLOE contributes to teachers feeling motivated, excited, affirmed and their efforts validated:

> *So meeting people who I hadn't met face to face and had similar interests who have been supportive with, just making comments on my work, or expressing an interest on twitter, or whatever, I felt affirmed I suppose. (Teacher 5)*

> *You know, you've got your ability to put things online and have people look at it and maybe use it and maybe give you feedback which, unless you're teaching the same subject as a colleague at the school you are in, you often don't have that potential. (Teacher 9)*

> *And it's validated that me constantly striving for something better, I'm not alone in that, that there's actually a lot of people out there. Because sometimes you look in a school and you think, oh, am I just weird? (Teacher 8)*

Table 5.3 below gives a summary of the experience of PLOE described in Category 3.

Table 5.3

A summary of the meaning and structure of Category 3

Category 3	
A. Meaning	Being part of something much bigger
Representative quote	*When you're engaging with colleagues and testing your understanding you're part of something much bigger than just one teacher in a school. I found it hard as the only IT teacher in a school, now I'm part of an IT teaching community, and that's because of the open Web and the kind of way that I'm learning. (Teacher 10)*
B. Focus of awareness	The interactive, social digital learning environment
C. How PLOE is differentiated from other professional learning experiences	Available knowledge, expertise, resources not limited to workplace context (school)
D. Critical aspects of awareness	
1. Focus of the Learning Experience	
Whose learning is in focus?	Teacher's
What is learning experienced as?	Social interaction, networked (teachers), global, affective, informal
2. Learning Practices What 'practices' do teachers engage in while experiencing PLOE (what they do to learn)?	Follow, observe, interact (share & communicate), participate in online events
3. Openness	
How is the open Web described as a learning context?	A 'world' different places, people and technologies; throw things out there; move around; interact with people; awareness of communities and networks. A journey, jump on, jump in, jump into; information is seen as a flow, feed, stream, trail
How is the culture of openness experienced?	Access to the whole world, democratic, respectful, empathetic, altruistic sharing, positive culture; awareness of attributing ownership of work. (open sharing, no attribution)
4. Learning Problems and Barriers What are the problems associated with the experience of PLOE (described as technical and/or personal)?	Compatibility problems, time zones Anti-social culture; disagreement, ugly side of social media, unprofessional, slow development of trust
5. **Validation of Learning** Who validates (approves, confirms, endorses, justifies, verifies, authenticates) the experience of learning?	Teachers judge/validate people: authenticity credibility Teachers validate each other: through feedback, approval, affirmation, sharing

5.1.4. Category 4: The Experience of PLOE as Building on the Ideas of Others

In Category 4, professional learning through Open Education is experienced as building on, and transforming, the ideas and resources shared by other people:

> *And now there's a name for it, whether it's maker-space or maker-ed or STEM lab or whatever, they're things that I have had an interest in and the open Web has provided me with the, I guess, the resources and the ideas to work in that area, and build on the ideas of others. (Teacher 5)*

Although this category describes teachers awareness of interacting with information, it is different to Category 2 in that teachers repurpose, and transform, information to suit their own learning and teaching needs. The focus of awareness in this category is the creative transformation of ideas and information. There is awareness that ideas are transformed, disseminated and amplified via the open Web:

> *Ahh, what else do I do? Like synthesise the information so I could post about particular resources that I think could be useful for other educators, so remixing it. (Teacher 5)*

> *I get excited by the way that you can amplify a good idea and when other people speak I can hear those good ideas and build on them. (Teacher 14)*

The experience of PLOE is differentiated from the more traditional, knowledge consumption experiences of professional learning, because teachers participate in the creation and dissemination of new knowledge. Due to the communal and collaborative nature of building on each other's ideas, both teachers' own learning and the learning of others are in focus. Learning is experienced as a practical, creative and collaborative process of problem-solving and design:

> *I conduct lessons that have been trialled and tested by other teachers and found to be successful. So you're not just recreating the wheel, you've got other people who've done something that's worked and you're building on that. (Teacher 5)*

So you've got your mixture of consumption, creation and there's also some collaboration. (Teacher 11)

It's remixing and trailing and rebuilding and evaluation...it is the design process too I suppose. (Teacher 5)

This long extract from the transcript of Teacher 14 illustrates this design process in action:

I wanted to work with a robotics project called The Little Maker Bots. We started off wanting to program an autonomous vehicle, we called the project the auto car where students do a little bit more than collision avoidance to try and look at inter vehicle communication. We bought a $20 cardboard vehicle, we bought a hummingbird kit for about $250, we managed to bolt together something that was quite big but it did the job and we learnt a lot on our journey. But, through me sharing that, and sharing that, and sharing that, I met up with some game programmers, I met up with some engineers, and then I met up with someone who said 'hey, do you realise what you've done in the last year, someone has a kit for a third of the price of what you've put together there's an actual kit you can buy which will do the same thing, and better. I'd have to admit that what I'd missed was that someone had started a kick-start project identifying the same need I had for a small, programmable robot that was affordable. Instead of me spending $300 on that, he had it for $100. It was a project called MacBlock and the mission was to have one robot per child, one laptop per child project. I'm wrapped, it does exactly what I want it to do and I've switched the project over to using that and it makes it a lot more affordable to run the project. In fact, we've now extended in those discussions from making an autonomous vehicle now to programming a smart city where I can handle the inter vehicle communication. That only happened because I put the idea out there and I was constantly sharing. And I wasn't doing it when I finished the project, and I'd done the report I'd done it much earlier in the stage. I'd done it in the stage where we were still developing a design brief, we presented what we thought was a rough outline, we put our drawings and diagrams out there. For me, actually sharing that out there, and taking on the chin

some of the criticism, I had the feedback I needed to have which meant that my project could move a lot faster. So, in some ways I guess our projects kind of modelling the way these projects can really quickly go through that iteration of development, solution and creation. (Teacher 14)

The 'Learning Practices' of teachers in this category, many of which are described above, involve communication, collaboration, giving each other feedback, and developing solutions to problems. Teachers engage in the creative practices of adapting and building upon the ideas and resources of other people. Individually and/or collaboratively, and occasionally in open source communities, teachers analyse, synthesise, make connections between, and add new knowledge to, each other's ideas. In addition to building upon each other's ideas, teachers spread good ideas by re-sharing their new knowledge via social media. Teachers also test and evaluate new resources, and ideas, in the classroom, and share their findings back into their networks on the open Web. In this way, learning is also experienced as fluid and ongoing:

It comes down to your connections, your conversations and sort of creating things together. It's not static, it's something you do, you'll always be learning. (Teacher 11)

The critical aspect of 'Openness', in terms of 'The open Web' as a learning context, is understood by teachers in this category as more than the networked, connected, democratic, and social learning environment described in Category 3. Firstly, there is awareness of becoming disconnected and lost in this environment while learning:

So you can get quite lost, easily, and you end up down this little rabbit hole of from one link to another to another and you're actually just another whirlwind of just thoughts and ideas, none of which are really concrete. (Teacher 16)

Thus, the open Web has become more of a 'community' and/or a personal/professional learning network (PLN) that reflects a broader culture of openness than what is described in

Category 3. There is awareness of identifying with, belonging to, and making valuable contributions towards communities/networks:

> *I see myself as being part of an education community and I think that's important because it gives me a sense of value for what I can contribute to the community and also for the skills I expect people to have when they become part of that community. (Teacher 14)*

'The culture of openness' also reflects expanded awareness of open licensing of resources. There is understanding of the process of using a CC license, when the work of others is repurposed and re-shared. Some teachers describe copying, sharing, remixing and re-sharing resources with Creative Commons (CC) licenses. Others express the desire to be acknowledged for their work, which they offer freely to others to modify, adapt and share, so that there is an awareness of the need for acknowledgment of the contribution of others in the community, suggesting that accountability to the community becomes important:

> *I expect to be acknowledged for my work, which you're free to modify, adapt and share, and infant share with modifications back to me. That's a Creative Commons license. (Teacher 14)*

> *I've taken their lesson plans and power points and adapted them to suit myself, under a CC license. I won't republish them because they are basically copied and pasted and added a few slides, so I'm not planning to republish them or share them publicly, but they were shared publicly. It was one case where I was happy to make a donation to that website in exchange for that information because it saved me so many hours, it just isn't funny. (Teacher 11)*

Thus, the awareness of the validation of learning expands to include recognition and acceptance of each other's repurposed ideas and resources, through re-use and re-sharing. Table 5.4 gives a summary of the experience of PLOE described in Category 4.

Table 5.4

Summary of the Meaning and Structure of Category 4

Category 4	
A. Meaning	Building on the ideas of others
Representative quote	*And now there's a name for it, whether it's maker-space or maker-ed or STEM lab or whatever, they're things that I have had an interest in and the open Web has provided me with the, I guess, the resources and the ideas to work in that area and build on the ideas of others. (Teacher 5)*
B. Focus of awareness	Repurposing/ transforming information and ideas
C. How PLOE is differentiated from other professional learning experiences	Contributing to knowledge creation and dissemination (not just a consumer of knowledge)
D. Critical aspects of awareness	
1. Focus of the Learning Experience	
Whose learning is in focus?	Teacher's and other people on the open Web
What is learning experienced as?	Creative, practical, individual and/or collaborative, a design process, problem solving, continuous
2. Learning Practices What 'practices' do teachers engage in while experiencing PLOE (what they do to learn)?	Copy, remix, repurpose, trial, re-share the ideas and resources of other people; work individually and/or collaborate
3. Openness	
How is the open Web described as a learning context?	A learning community personal/ professional learning network (PLN), a place to 'resonate' ideas; awareness of the 'value' of making contributions; a place to feel lost and disconnected
How is the culture of openness experienced?	Open source communities, making modifying the work of others in the community; greater awareness of CC license, attribution and re-sharing of modified resources, continuous improvement (Developing awareness of OE cultural norms; need for accountability to the collective)
4. Learning Problems and Barriers What are the problems associated with the experience of PLOE (described as technical and/or personal)?	Same as Categories 1 to 3
5. Validation of Learning Who validates (approves, confirms, endorses, justifies, verifies, authenticates) the experience of learning?	Teachers validate each other: re-use of work, re-sharing

5.1.5. Category 5: The Experience of PLOE as Learning While Teaching

In Category 5, professional learning through Open Education is experienced as teachers learning in context of their classrooms, while teaching their students STEM subjects. For example, when teachers, and their students, face problems in the classroom, they can learn immediately by drawing on the expertise of other people on the open Web:

> *Well, I got my kids to work on Scratch, towards the end of last year and the students pushed software into directions that I didn't even know you could do and I couldn't help them at all cos my knowledge is limited. So I looked on my Skype group called Hello Little World Skypers', and one of my friends, LL, whose very good at Scratch, who works on the world museum global projects in Scratch, she was online. So I said LL could she come in and show the students where they were going wrong cos they couldn't fix their code. So I put the iPad on the kid's screen. First the kids had the screen showing her to introduce themselves, then reversed the camera so she could actually see the code and where they were making errors, and they could then fix it up and then pass her on to the next student who was having the same problems. So not only was I learning but the kids more importantly were learning what they needed to, just when they needed to. (Teacher 1)*

The focus of awareness in this category shifts into the classroom, where teachers learn with, for, about and sometimes from their students. It is about the way PLOE is used as a pedagogical approach, to enhance teacher and student learning in the classroom. This experience involves teachers interacting face to face with students in a physical classroom (which includes physical excursions), while using information, and the expertise other people from around the globe, which are accessed in real time on the open Web. In this experience of PLOE, teachers learn while they are teaching. This is different to more commonly experienced professional learning that is external to the classroom context.

The experience of learning in this category is not just about teachers using the open Web for their own learning, in order to prepare for teaching. Students are not just the recipients of what teachers create, devise or plan. The learning of both teachers, and their students, is in focus. The motivation for, and the experience of teachers' learning is situated in the practice

of teaching, which is tied to student learning in the classroom. It's about pedagogical transformation – teachers and students learning together, in real time, in the classroom. Students are engaged with the teacher in the process of PLOE. So PLOE is situated in the practice of teaching. In this category, awareness of the networked nature of learning on the open Web is extended into the realm of students' learning:

> *I think it's networked learning that I like too. I think what I want to do is try and establish a network for my students too. (Teacher 1)*

Learning is experienced as filling knowledge gaps, (like in Category 2, but situated in the practice of teaching), for example, see the experience of Teacher 1 above. Learning is also experienced as connected, where teachers make connections between what they learn elsewhere on the open Web, to the content of learning in the classroom and/or on school excursions. For example, the experience of PLOE described by Teacher 7 below highlights awareness of making connections between new knowledge gained from a MOOC, and sharing that knowledge with students on a school excursion:

> *I learned a lot of stuff that I would of never thought about before. Like one of the questions explored in the MOOC was 'how did life begin?' As a chemistry person...well, molecules right? There was one reading that they gave us that was all about these little organisms that have evolved millions of years ago and apparently, and I'm shocked that I didn't know this as a chemistry teacher, the oceans were full of resolved iron. No idea, right? But I had been up to the museum to try and design a field trip for year 9 students and there was this massive rock that had these layers of iron that had just sort of precipitated out and formed on the ocean floor. As I was doing the reading from the MOOC I thought, 'oh my god, that's what the thing in the museum is'. So I did the MOOC and when we went to the museum with the year 9s, and this is like the kind of teacher I am, I was like 'oh hey, come over here' like, to a couple of groups 'do you know what this is? This is amazing' and I was able to explain to them what was happening and the little organisms that were producing oxygen and allowing that iron to precipitate out of iron oxide and stuff like that. And I was like*

'you know, this is like 3.8 billion years older, or whatever'...and I think that opened me up to something that firstly, wasn't in any of the textbooks and a connection there that I could make to geology, to biology and to chemistry. (Teacher 7)

In this category, learning is also experienced as serendipitous, and current. For example, when scientific discoveries are announced on social media, teachers and students keep up to date with contemporary information not available in textbooks:

Year 10s have astronomy first term, and astronomy...it's a hard arse teaching astronomy to 14 and 15 year olds...but one of the things is…some of the older teachers really like teaching astronomy and I said "how do you like it when you don't ever know what you're saying is actually true, because it changes like every year?" And while I was teaching it this year they found the gravitational waves and I'm going "ahh guys, hang on, hang 10, this all happened yesterday, and it's live on Twitter, it's not in the textbook". Yeah, so the discussion for that day is, I showed them all the stuff that was coming out about this new discovery and how amazing it was and then they had to actually, in groups, work out how that new knowledge effected what I'd already taught them and what they previously knew. They got so frustrated because they're studenting, they just say "tell me what the stuff is and I'll regurgitate it in the exam, and we'll all be happy", and I'm going "you can't, because every month there's something that makes you question what you were told before". So you're trying to piece together stuff and you try to teach kids while it's still actually happening, and I think that's great. (Teacher 8)

The experience of learning can also be immediate:

> *...if the students in class have got a problem with their software or tools that they want to use, if I put it out on Twitter or somewhere I almost get an instant reply so the student can do it straight away rather than waiting another week till I have them again, and they've lost that excitement and passion with what they wanted to do because they got frustrated. So the frustration levels are less and less because you've got that ability to fix or solve whatever you want to do, immediately. (Teacher 1)*

The 'Learning Practices' of teachers in this category are similar to the practices described in Categories 1 to 4, but in this category they occur in a physical classroom. Teachers use their technical and/or social skills to learn for themselves, and their students. Teachers describe 'reaching out' to their learning networks on the open Web to support their teaching in a number of different ways. For example, video conferencing platforms are used to bring knowledgable others, including interpreters, into the classroom, via the open Web. This means there are no longer language barriers when teachers and their students seek real time, global perspectives about STEM education during their lessons:

> *I've been able to make connections and have discussions either via Skype or Google hangout with specialists in that area in the classroom. (Teacher 12)*

Information, in the form of authentic, real time data, is collected via social media and used as content for student learning in STEM subject areas (for example, collecting the temperatures of cities from around the globe):

> *If we're doing things like spread sheets in computers I try and get data through Twitter or through my networks and so they tell us what the current temperature is, the kids graph the temperature etc... (Teacher 1)*

Teachers learn about their students' progress, and students learn through receiving immediate feedback when web tools are used for generating, collecting and analysing student data, in real time:

> *I think the other thing that the open Web provides too, is a lot more opportunity to generate data and analyse that data as well. This is all of those things that is so different from back in the days when you were marking lab books and you were recording the marks in the back of your chronicle or something like that. That's kind of nice because you can see 'oh well, I asked this question and 2/3 of the kids got it wrong, maybe I need to revisit that. Or the other option is you look at it from the point view of how individual students perform. That's just something on the open Web. (Teacher 4)*

As with the previous four categories, the open Web is seen as a digital context for learning. In this category, the open Web is experienced as extending the learning context of a physical classroom into a global, digital classroom:

> *Sometimes we work through an interpreter. Once we worked with this class in Japan, my students would ask questions, their students didn't understand so the teacher would interpret. So we had to wait, listen for the interpretation, get it back in English and then we'd get on with the next question. So that was a different way of learning and to work through a third person. (Teacher 1)*

In Category 5 the culture of openness refers to people making themselves available to help others (teachers and students); the altruistic culture of improving things for the benefit of the teaching community. Awareness broadens to the use of open textbooks for student learning and using resources with a Creative Commons license to avoid violating copyright. In other words, there is increasing awareness of what OE actually is, and the associated cultural norms and pedagogical practices.

With respect to Learning Problems and Barriers, the reliability of internet connections came into focus again in Category 5, when teachers engage in PLOE while teaching. Additionally, blocked websites, language and international time zone barriers and the suitability of certain resources were technical problems described in this category. Personal problems were related to language barriers, and student discontent with new pedagogical approaches adopted in the classroom. Teachers feel validated through their students' learning in Category 5. For example, improved interest in and behaviour during lessons elicits feelings of validation that teachers are making a difference to their student's learning.

Table 5.5 below gives a summary of the experience of PLOE described in Category 5.

Table 5.5

Summary of the Meaning and Structure of Category 5

Category 5	
A. Meaning	Learning while teaching
Representative quote	*Well, I got my kids to work on Scratch, towards the end of last year and the students pushed software into directions that I didn't even know you could do and I couldn't help them at all cos my knowledge is limited. So I looked on my Skype group called Hello Little World Skypers', and one of my friends, LL, whose very good at Scratch, who works on the world museum global projects in Scratch, she was online. So I said LL could she come in and show the students where they were going wrong cos they couldn't fix their code. So I put the iPad on the kid's screen. First the kids had the screen showing her to introduce themselves, then reversed the camera so she could actually see the code and where they were making errors, and they could then fix it up and then pass her on to the next student who was having the same problems. So not only was I learning but the kids more importantly were learning what they needed to, just when they needed to. (Teacher 1)*
B. Focus of awareness	Pedagogical applications – students and teachers learning together
C. How PLOE is differentiated from other professional learning experiences	Not separated from/ preparation for real-time teaching; not just about teachers' learning
D. Critical aspects of awareness	
1. Focus of the Learning Experience	
Whose learning is in focus?	Teacher's and student's
What is learning experienced as?	Situated in the practice of teaching, flexible (teachers and students); networked (teachers and students); serendipitous; current; immediate and a pedagogical approach
2. Learning Practices What 'practices' do teachers engage in while experiencing PLOE (what they do to learn)?	Engage in the practices of Categories 1 to 4, while teaching in a physical classroom
3. Openness	
How is the open Web described as a learning context?	Extension of the learning context of a physical classroom into a global classroom.
How is the culture of openness experienced?	Availability of people to help; altruistic culture of improving things for the benefit of the community, the PLN. Awareness of open textbooks, not violating copyright, use of CC license. (Increasing awareness of what OE actually is, and the associated cultural norms and pedagogical practices)

4. Learning Problems and Barriers What are the problems associated with the experience of PLOE (described as technical and/or personal)?	Same as Categories 1 to 3 in the classroom context; blocked websites; language barriers; student discontent
5. Validation of Learning Who validates (approves, confirms, endorses, justifies, verifies, authenticates) the experience of learning?	Teachers are validated through their student's learning

5.1.6. Category 6: The Experience of PLOE as Personal and Professional Change

In Category 6, professional learning through Open Education is experienced as personal and professional change, such as change in teachers' practices, behaviours, assumptions, beliefs and emotions:

> *Well I suppose the biggest thing I've learnt is the power of the conversation and that online learning is a very valid, probably a better form of professional learning, which has completely transformed the way I teach, the way I see the world, and myself as a person. (Teacher 11)*

The focus of awareness in this category is on how personal and professional change emerges from the experience of PLOE. The experience of PLOE is differentiated from other professional learning experiences in that its value is not externally validated. Teachers judge the value of their experiences themselves, through reflecting on (recognising and accepting) their experiences, and the experiences of others, and how, and in what ways, they have changed.

'Learning' is an individual experience, where only the teachers' learning is in focus. It is also a reflective experience, where teachers learn by acquiring information about themselves, through reflection on their own experiences, and the experiences of others. This gives teachers access to what others think of them, and provides a way for teachers to judge themselves against what other's write, say and do. Through reflecting on what they do in the classroom, teachers understand more about themselves as teachers, for example, as becoming more confident and open minded. This comes from teachers knowing they can access their digital network on the open Web, while they teach, for information and/or help when it is needed:

> *I think I've become far more confident over time now that I'm not an expert, happy to go out there and learn with them and learn for myself. (Teacher 1)*

Now I'm game to have a go cos I know I can go out there and find out what I need to know to help the students either by my network or by searching or by using hashtags, or whatever. (Teacher 1)

I think it's helped keep me really open minded and I guess innovative and fresh in terms of my ideas I would say, seeing that lots of people are out there. (Teacher 16)

Teachers also gain confidence through reflecting on what others post on social media:

It also gives me confidence too, because a lot of things I see people tweet and I'm like 'oh yeah, I do that already or I thought of that first or I do that better'. In that sense it definitely has an impact on many aspects of what I do. (Teacher 16)

Teachers are aware that change in beliefs can lead to a change in behaviour:

Along that journey I'm learning and I'm changing my beliefs about what I want out of this project and I'm kind of assimilating the knowledge that other people are giving to me. If learning is a change in behaviour, well the way I'm managing this project and the way I'm heading with this project, changed. (Teacher 14)

Assumptions and perspectives can be challenged by other people who make alternative and controversial comments. This stimulates reflection on pedagogy and practice, resulting in change of attitudes and/or practice:

OK, so if a statement is made online that makes me, sort of jerk back a bit and think 'oh, do I agree with that or if I disagree, why do I disagree?' (Teacher 5)

But I'm finding that a lot of it, sort of reflecting on it, I think a lot of it is more internal redirection of belief and challenging assumptions, as opposed to this is how you do x. Yeah, I definitely feel like it's more attitudinal changes than specific practice changes I think, if that makes sense. (Teacher 2)

There is evidence of affective change in this category; along with transformative change, for example, as Teacher 11 described in the opening paragraph of this section:

> *I have become a lot more passionate and it's exciting. (Teacher 1)*

Learning is experienced as intercultural understanding and identity formation. Seeing oneself as a more confident user of social media comes from knowing that a balance can be found between one's personal and professional identities in public, digital spaces:

> *I've learnt a lot more about myself and Australia by connecting….I really enjoy understanding learning about other cultures, people and what it's like where they live, how they feel about us etc. I've probably learnt more about me as an Australian citizen too, you know, how lucky we are to live where we do. And that's something I always tell the students too. (Teacher 1)*

> *I will be who I jolly well like on twitter. I will present professional, you know twitter, social media, I'll be myself. (Teacher 11)*

Learning is also experienced as pedagogical change. For example, Teacher 14 became less rigid and more student-centred in their pedagogy:

> *So, my change has probably a little more aligned to where students are coming from. And it wasn't something I could learn from a course. (Teacher 14)*

With respect to the 'Learning Practices' of teachers in this category, learning happens when teachers observe how others participate on the open Web. This can bring about reflection on ones' pedagogy and capabilities.

It can also build confidence, reassurance, and elicit feelings of empathy knowing there are other teachers in Australian classrooms similar to themselves, who are teaching similar things and are feeling the same way as they do:

> *Lurking, we'll go with lurking. Even though they sort of call it that, I think I do pick up things that you can either agree with or disagree with or have a think about it and sometimes that's as powerful, you know, questioning your own ideas and understandings is quite powerful rather than necessarily finding something that you're going to go into a classroom and give to a student as an activity. (Teacher 10)*

> *It's not all about finding materials, sometimes it's seeing what other people are thinking or what people are even feeling about teaching as well. Though sometimes you'll read a tweet in a thread, and they're saying 'oh I'm feeling frustrated' and I'm going 'ah a men, someone out there is feeling the same way I am as well. (Teacher 4)*

Learning also happens when teachers reflect on the conversations they have with people on the open Web:

> *I think in some ways it's made me more reflective, because I'm constantly involved in random conversations as well as scheduled chats. I'm more conscious of what my practice is like because it's often a part of the conversation on Twitter because the question will often be practice driven, in some way it will tie into practice and I'm finding that I'm reflecting a lot more and being aware of what I'm doing in the classroom (Teacher 2).*

Learning happens when teachers reflect on events organised by others, on the open Web, they participate in; pedagogical change as consequence of their experience of PLOE:

> *The global collaboration presentation that I watched really encouraged me to think more carefully about how I can use learning experiences to connect my students with the wider world and that was obviously through the means of technology so in some ways I thought about how I thought I could use the technology more effectively to bring a bit more of a global aspect into the classroom. (Teacher 12)*

> *And I think that you know, by taking this course, although it was geology, I was made aware of how we can use earth science as really a way to connect all of the sciences together. So as a teacher, now I'm thinking, whenever I do the earth science unit I'm trying to make those connections much more obvious to the students than you know, like, I guess, some teachers that say 'oh, geology, rocks, that's it'. (Teacher 7)*

The open Web, as a learning context, is experienced in Category 6 as a public place that induces feelings of insecurity:

> *One of the scariest most confronting things is putting yourself out there to the public, your views out there to the public….when you put yourself out there, you're going 'am I just talking rot, you know, do I just sound like I'm a complete idiot?' (Teacher 8).*

It is also experienced as having the world in the room with you, while learning. This is different to Category 4 where the community/network is imagined to be external to the teachers' place of work:

> *Well, I think because of my...this is the global education conference, you know the conference that runs 3 days, you have the world in the room with you. People from Egypt, Syria where the war zone is, etc. It's an amazing thing, you know you reading about what's happening in their countries in the paper and here they are online with you wanting to learn the same things as you. (Teacher 1)*

Along with this global understanding of the open Web as a learning context, as mentioned above, the culture of openness broadens in this category to include inter-cultural understanding. Openness has also become more than a being aware of open licensing. For example, this teacher sees it as a way of thinking:

> *I think a lot of people recognise now to see if it's got a licence and then pushing it. So, I think our whole way of thinking...don't keep everything tight to ourselves, it's our area, you know, our protected area...lets get it out and pushing it around. (Teacher 1)*

In this category there is awareness of sharing, as a feature of the culture of openness, being problematic:

> *There are some teachers who will quite willingly share what they do, I try to. I share my reflections of my experiences, sometimes I share too much, as I discovered recently. Yeah, someone got a bit upset, but that's OK. (Teacher 11)*

No new technical problems and barriers emerged in this category, however there is an increased awareness of more complex personal problems and barriers related to the experience of PLOE. Personal problems relate to teachers reflecting on, and being aware of, their own behaviour and feelings about using social media for professional learning. For example, being blunt, being seen by others as a trouble maker, people not accepting their input, lacking confidence, feeling scared and alone. There are times when teachers question their ability to make a valuable contribution at all, or whether their contribution will be misunderstood.

Comparing oneself to so many teachers on the open Web also generates reflection and pressure, on self, as a professional:

> *So there are those perhaps psychological barriers in the open Web as well. You're not going to reach out in communities where you feel you don't have the confidence to make any valuable input. (Teacher 5)*

I've gotta confess, I do feel that there's a certain amount of indirect pressure...I wouldn't even say that it's coming from management, but because of the information that you're pulling in from all over the place you do sort of feel, you know, like I said, you do worry a little bit. You sort of think, am I riding the crest of the wave or am I behind it or where am I in the overall scheme of things? So, I do feel a little bit of indirect pressure just to make sure I'm doing all of the things that should be done? (Teacher 4)

In Category 6, the experience of learning is validated by teachers themselves when they find effective ways of teaching; through the respect and friendship of other people; and through feedback from experts on the open Web:

I think I've mentioned it's given me a lot more confidence as a teacher, that my ideas are valid and that I don't have to follow the path of the teachers at my school necessarily, that there's other ways of teaching and other effective and successful methods. (Teacher 5)
I think I used to be reasonably shy but having an online presence has really pushed me out, has given me confidence, has given me, you know, some level of esteem amongst other people. It's given me camaraderie, a different way of trying to connect and communicate. (Teacher 1)

Yeah, it has, it has changed the way I view myself.……I think I'm a fairly solid teacher, this is one of the ways that I can actually check whether I am on the right track or not, or I'm barking completely up the wrong tree?..... Now, having a chat with DW, then you go...no no no, I actually do sort of know what I'm talking about so in terms of me, as a professional, I'm a lot more confident that my practice is embedded in research and fact rather than just gut feel. (Teacher 8).

Table 5.6 below gives a summary of the experience of PLOE described in Category 6.

Table 5.6

Summary of the Meaning and Structure of Category 6

Category 6	
A. Meaning	Personal and professional change
Representative quote	*Well I suppose the biggest thing I've learnt is the power of the conversation and that online learning is a very valid, probably a better form of professional learning, which has completely transformed the way I teach, the way I see the world, and myself as a person. (Teacher 11)*
B. Focus of awareness	Reflecting on what brings about personal and professional change
C. How PLOE is differentiated from other professional learning experiences	Value of PLOE not externally validated
D. Critical aspects of awareness	
1. Focus of the Learning Experience	
Whose learning is in focus?	Teacher's
What is learning experienced as?	Reflective, change, understanding, transformation, inter-cultural
2. Learning Practices What 'practices' do teachers engage in while experiencing PLOE (what they do to learn)?	Reflect on what is seen, heard, done and felt regarding Categories 1 to 3, and possibly but not explicitly Categories 4 and/or 5
3. Openness	
How is the open Web described as a learning context?	Public place; people from around the world in the room with you.
How is the culture of openness experienced?	Inter-cultural understanding. More than licensing of content, way of thinking. (OE becomes a way of thinking)
4. Learning Problems and Barriers What are the problems associated with the experience of PLOE (described as technical and/or personal)?	Awareness of the limitations of one's own feelings and behaviour. Indirect pressure
5. Validation of Learning Who validates (approves, confirms, endorses, justifies, verifies, authenticates) the experience of learning?	Teachers validate themselves through what they, and others, experience

5.2. Structural Relationships Between Categories: Towards the Outcome Space

The six categories of description elaborated above represent the range of qualitatively different ways Australian teachers of STEM subjects experience professional learning through Open Education, and as such, provide the answer to RQ1: What are the different meanings Australian teachers involved in STEM education attribute to the experience of PLOE? While the overall meaning (referential component) captured in the title of each category shows that the experience of PLOE in each category is qualitatively different, the focus of awareness (structural component) helps to further differentiate the experience of PLOE in each case. Similarly, variation in the experience of PLOE can be seen in terms of C (How PLOE is differentiated from other professional learning experiences), a D (The critical aspects of awareness). Variations in the experience of PLOE (in terms of A, B, C and D) in each category are summarised in Table 5.7.

Table 5.7

Variation in Referential (A) and Structural Components (B, C and D) of the Six Categories of Description

	Category 1	**Category 2**	**Category 3**	**Category 4**	**Category 5**	**Category 6**
A. Meaning	Reclaiming Autonomy	Filling knowledge gaps	Being part of something much bigger	Building on the ideas of others	Learning while teaching	Personal and professional change
B. Focus of awareness (structural component)	Opportunity for, and flexibility of learning	Finding useful information and resources	The interactive, social digital learning environment	Repurposing/ transforming information and ideas	Pedagogical applications: students and teachers learning together	Reflecting on what brings about personal and professional change
C. How PLOE is differentiated from other professional learning experiences	Unregulated, not mandated	Open (not firewalled), current (not out-of-date), personalised, (not standardised)	Available knowledge, expertise, resources not limited to workplace context (school)	Contributing to knowledge creation and dissemination (not just a consumer of knowledge)	Not separated from/ preparation for real-time teaching; not just about teachers' learning	Value of PLOE not externally validated. Internal validation by teachers themselves

D. Critical aspects of awareness	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6
Whose learning is in focus?	Teacher's	Teacher's	Teacher's	Teacher's and other people on the Web	Teacher's and student's	Teacher's
What is learning experienced as?	Flexible, self-directed, bottom-up	Deliberate and/or serendipitous, ad-hoc, top-up, bite-sized	Social, interactive, networked	Creative, practical, individual and/or collaborative, problem solving	For teachers and students: situated, flexible, networked	Reflective, change, understanding, transformative, inter-cultural
Learning practices	Teachers decide what, when, where, how and why to learn	Teachers access, search for, manage, archive, use information	Teachers follow, observe, interact with people, and participate in events	Teachers repurpose, trial, and re-share their own, and others' resources	Similar to Categories 1 to 3, possibly Category 4, while teaching in a physical classroom	Teachers reflect on what they see, hear, do and feel regarding Categories 1 to 3, and possibly Categories 4 and/or 5
The open Web as a learning context	A thing	A place to move around in, to search for, find and 'pull in' information from	A 'world' of different, connected, places, technologies and people; interactive; a 'journey'; information 'flows' in a stream/feed	A learning community/ PLN; a place to 'resonate' ideas; where contributions are valued; a place to feel lost and disconnected	Extension of the learning context of a physical classroom into a global classroom	Public place, inter-cultural, global, education community
The culture of openness	Accessibility	Acquisition	Open sharing, no attribution	Developing awareness of OE cultural norms; need for accountability to the collective	Increasing awareness of the nature of OE; associated cultural norms and pedagogical practices	OE becomes a way of thinking

D. Critical aspects of awareness (continued)	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6
Learning Problems and barriers	Poor internet access, connectivity and speed	Variable quality of content and websites; information overload, losing/wasting time	Compatibility problems, time zones; anti-social culture; ugly side of social media	Same as Categories 1 to 3	Same as Categories 1 to 3 in the classroom context; blocked websites; language barriers; student discontent	Awareness of the limitations of one's own feelings and behaviour.; indirect pressure
Validation of Learning	Teacher registration authorities may validate PLOE if provided as evidence of PL	Teachers judge/validate information (authenticity, quality, relevance, credibility)	Teachers judge/validate other people (their authenticity, credibility); validate each other (feedback, affirmation, sharing)	Teachers validate each other through re-use and re-sharing of each others' content	Teachers are validated through their student's learning	Teachers validate themselves through what they, and others, experience

The critical aspects of awareness (D), and their corresponding features in each category, provide the answer to research sub-question two: What aspects of PLOE are critical to the different ways this phenomenon is experienced by Australian teachers of STEM subjects? These aspects also account for the structural relationships between the six categories of description, which are referred to as themes of awareness, and represent changes in awareness of each critical aspect from Category 1 through to Category 6. These changes are discussed in the following sections, and throughout the next chapter.

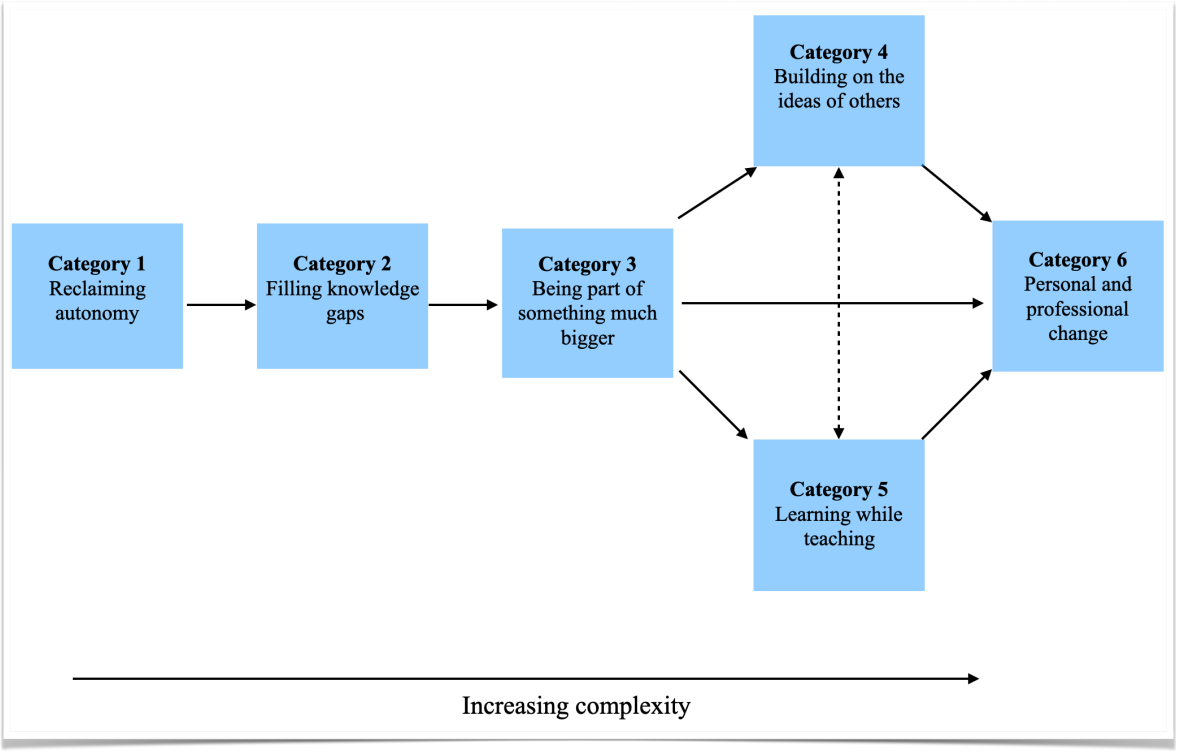
The six categories of description, along with the five critical aspects that constitute these categories, combine to form the outcome space. In the next section I present a broad discussion on the inclusivity of relationships between Categories 1 to 6, based on logical argument and empirical evidence in the form of interview extracts. Based on this discussion the shape of the outcome space is justified.

5.4. The Shape of the Outcome Space

Figure 5.8 below illustrates the six categories of description within the outcome space. The categories are arranged from simple to more complex ways of experiencing PLOE, on the basis of inclusivity, meaning of the the experience of each successive category includes awareness of many of the features described in previous categories, plus something new. In the following discussion I draw on empirical evidence in the form of interview extracts in combination with logic to argue how the six categories of description are related to form an outcome space.

Figure 5.8

The Non-linear Structure of the Outcome Space



As illustrated in Figure 5.8, the way PLOE is experienced becomes increasingly complex, beginning with the simplest category on the left (Reclaiming autonomy) moving to the most complex category on the right (Personal and professional change). Increasing complexity is due to the inclusivity of categories. This means the experience of PLOE described in

Category 6 includes awareness of more features than the experience described in Category 1, making it a more 'complete' experience (Akerlind, 2015, p. 8).

Phenomenographers see the outcome space as representing the whole experience of a phenomenon, thus PLOE can be seen as a 'complex' of the different ways teachers experience it (Reed, 2006, p. 3). It is assumed that Categories 2 to 6 are all inclusive of Category 1 (Reclaiming autonomy). While reclaiming autonomy (having choice and independence over their professional learning) leads to the experience of Category 2, awareness of the experience of PLOE expands in this category. It now includes teachers building their knowledge of STEM education. For example, Teacher 1 describes the flexibility of learning (Category 1) by finding the learning materials immediately:

> *I just think the big difference much of the time is that I can learn right now. I don't have to spend days and weeks researching, trying to find the right materials. (Teacher 1)*

While Category 3 includes Categories 1 and 2, PLOE is also experienced as an expanded professional learning environment involving different places and people on the open Web. Evidence for the inclusivity of Categories 1 and 2 in Category 3 is illustrated by the quote below. Teacher 8 describes meeting her needs with the choices she makes (Category 1), finding resources to meet her needs (Category 2) and interacting with people (Category 3):

> *You can actually tailor the information you get to exactly your needs. You can ask them the question you always wanted to ask, or give them the scenario you're struggling with. So I found it hugely beneficial and a bit of an eyeopener really. You know, it's all very well finding resources and this sort of stuff, but the interaction has been, I don't know, probably not as much learning as maybe, you know, reading something, or whatever, but I suppose it beats being motivating me to go further in terms of investigating various things that may improve my practice, or you know, keep me interested in teaching. (Teacher 8)*

While Category 4 includes features of the previous three categories, the use of information for learning moves back into focus. To this point teachers describe the importance of reclaiming their autonomy (Category 1), their ability to fill in their knowledge gaps (Category 2) and their awareness of learning in different places on the open Web, in the presence of other people (Category 3). Unlike Category 2, where information is used by teachers to fill in their knowledge gaps, in this category the experience of PLOE expands to awareness of learning creatively with information and people on the open Web. Information is seen as ideas that people have, adapt, build upon, improve and re-share, in creative ways, for a new purpose. The inclusivity of Categories 1, 2 and 3 within Category 4 is evidenced by this quote:

> *It's more than just the information that I can access, it's about the connections and the communication, the ways to build up, I think DN calls it collective knowledge. So being part of a professional learning network, in a very informal way, that can bounce ideas off each other, and in your own school test and trial, and communicate with others online and reflect on that practice. It is much more than just a bucket of information. It's remixing and trailing and rebuilding and evaluation. It is the design process too, I suppose. (Teacher 5)*

Teacher 5 recognises the experience of PLOE as being more than finding information and people, and more than connecting to and communicating with people in networks. She is aware of learning through a process of building upon and improving the ideas people share on the open Web.

Category 5 is inclusive of Categories 1, 2 and 3, yet is not dependent on being reached through Category 4, however, there is some overlap. To recap, in Category 4 teachers experience PLOE as building on the ideas of others, sometimes as a way to develop and improve STEM projects in their schools. This may include teachers engaging in PLOE while they teach, yet that feature is not made explicit in Category 4. However, it is in Category 5, which expands the experience of PLOE into the realm of the classroom. In this category, teachers access the open Web, while they teach, to learn with, for, from and about their students when different pedagogical approaches are used in the classroom. Information

moves in and out of the classroom via the open Web. For example, the quote below provides evidence for the relationship of this category to Categories 1, 2 and 3:

> *Sometimes I'm teaching coding, I don't know a lot about that so I reach out on Twitter or on my Skype networking groups to find someone that might help me a little bit more and the students when they need help. (Teacher 1)*

Teacher 1 is not building upon the ideas of others to be creative, she is learning about coding with her students. She has gaps in her knowledge, and used her network to find someone to help her students progress with their learning, and in doing so, helped herself. Bringing someone into the classroom, via the open Web, is a new pedagogical approach to teaching. It is also a new approach to professional learning. This experience of PLOE is an expansion of Category 3 and overlaps with Category 4 if teachers build upon the ideas of others while they are teaching. In other words, the experience of PLOE described in Category 5 does not necessarily include building upon the ideas of others. Category 5 is reached directly from Category 3, but is related to Category 4 if the ideas of others are built upon while teachers are teaching.

Category 6 is inclusive of Categories 1, 2 and 3, and can be reached through, but is not dependent on, Categories 4 or 5. To recap, in Category 3, PLOE is experienced as being part of something much bigger, where teachers are aware of learning in different places, in the presence of other people, on the open Web. This experience, in its own right, can lead to teachers learning more about themselves. For example, Teacher 8 describes reflecting on her Category 3 experience as being purposeful because if provides the evidence/backup that 'things' (information/resources) she finds on the open Web can be effective for student learning:

> *So reflection being the tool of the trade, you can reflect and go 'this is not going so well, I can try this, I can try that' but actually what it has done is reflecting with a purpose. Like, why would I try this, where is the evidence for trying this? You've got limited resources in terms of time and now, for me, energy as well. I've got to try the thing I think is going to be the most effective, that has some backup for being effective,*

not just like 'chuck this at the wall and see if it sticks'. Effective in terms of, you know, students understanding, engaging, you know, all of those sorts of things. Things that formative assessment will allow you to pick up. (Teacher 8)

Additionally, the experience of Category 6 may or may not arise from teachers building upon the ideas of others (Category 4), or learning while teaching (Category 5). The journey to Category 6 can be made directly from Category 3, through Category 4 or 5. Teachers reflect on what they see, hear, do and feel regarding Categories 1 to 3, and possibly but not explicitly Categories 4 and/or 5. Overall, in this category, teachers describe their experience of PLOE as having an impact on how they see themselves. Based on this discussion of the inclusiveness of each category it is clear the shape of the outcome space is not a linear hierarchy.

5.3. Chapter Summary

This chapter outlines the findings that emerged from empirical research into the question: What are the different ways in which Australian teachers of STEM subjects experience professional learning through Open Education?, and the associated sub-questions RQ1 and RQ2. Variation of experience is described in six categories of description titled: Reclaiming autonomy, Filling knowledge gaps, Being part of something much bigger, Building on the ideas of others, Learning while teaching, and Personal and professional change. By virtue of the same phenomenon being experienced these categories are related to each other structurally, through five critical aspects: Learning, Practices, Openness, Problems and barriers, and Validation. These five critical aspects have different features in each category which, when connected, form themes of awareness. The six categories of description, along with the five themes of awareness, combine to form a non-linear outcome space transitioning from simple to more complex ways of experiencing PLOE.

Thus, variation in the experience of PLOE is presented in several ways throughout this chapter. Firstly, the six categories of description vary in meaning. Secondly, the focus of awareness and the five critical aspects in each category constitute variation in structure and account for the non-linear shape of the outcome space. Thirdly, the features of each critical aspect vary across the six categories of description forming themes of awareness. The whole

phenomenon of PLOE is represented by the six categories of description and five themes of awareness that represent their similarities and differences. In the next chapter a developmental phenomenographic perspective is used to discuss these findings, along with the usefulness of applying the outcome space to the professional learning of teachers of STEM subjects.

CHAPTER 6. DISCUSSION AND CONCLUSION

This final chapter provides a discussion and summary of how my findings address the research problem from which this study emerged, that teachers' perceive their professional learning experiences lack effectiveness, meaning, and relevance to their classroom practice. First, I present a synthesised response to the research questions. Next, the Professional Learning through Open Education (PLOE) Framework is introduced, and its foundations and design features are discussed. These are drawn from the literature on the features of effective professional learning and effective digital networks, and the digital capabilities needed for learning in complex digital environments. Uses of the PLOE Framework are then recommended. Contributions of this study to the fields of professional learning and Open Education are then discussed, in the context of teachers' work and STEM education. Finally, future directions for further research are suggested, and my concluding thoughts are given.

6.1. Synthesised Responses to the Research Questions

The aim of the study was to explore the different ways Australian teachers involved in STEM education experience the phenomenon of professional learning through Open Education (PLOE). To generate findings applicable to this aim, developmental phenomenography was used to explore the main research question: What are the qualitatively different ways that professional learning through Open Education is experienced by Australian teachers involved in STEM education? This question was approached through three sub-questions:

> RQ1: What are the different meanings Australian teachers involved in STEM education attribute to the experience of PLOE?
>
> RQ2: What aspects of PLOE are critical to the different ways this phenomenon is experienced by Australian teachers involved in STEM education?
>
> RQ3: How can the new knowledge gained from RQ1 and RQ2 be used to design professional learning experiences for Australian teachers involved in STEM education?

In response to RQ1, the findings reveal that six different meanings were attributed to the experience of PLOE: Reclaiming autonomy; Filling knowledge gaps; Being part of something much bigger; Building on the ideas of others; Learning while teaching; and Personal and professional change. In response to RQ2, five aspects of PLOE were found to

be critical to the way this phenomenon was experienced: Learning; Learning practices; Openness; Learning problems and barriers; and Validation of learning. These findings related to RQ1 and RQ2 were combined to form the outcome space as seen in Figure 5.8 (p. 168). The response to RQ3 fulfils purpose of developmental phenomenography, that is, to use research findings to address "the particular practical issue that was the genesis of the research" (Green & Bowden, 2009, p. 52). It is also the essence of the Professional Learning through Open Education (PLOE) Framework, developed on the basis of the outcome space, and which constitutes this study's primary contribution to knowledge.

In the next section I begin with an introduction to the PLOE Framework and its theoretical foundations. This is followed by a discussion of the ways in which the framework can be used to inform the design and delivery of meaningful professional learning for teachers who work in a similar context to those who participated in this research.

6.2. The Professional Learning through Open Education (PLOE) Framework

To develop the PLOE Framework my findings are seen through the lens of the *"Variation Theory (of Learning)"* (Marton & Pang, 2013, p. 24). This theory is based on phenomenography, has been tested by researchers and K-12 teachers via the Learning Study framework over many years, and is used as a "pedagogical tool" by classroom teachers (Lo, 2012, p. 17). As I mentioned in Chapter 2, Learning Study is also an approach to K-12 teachers' professional learning that aims to help teachers become more aware of, and sensitive to, learning from their students' point of view (Pang, 2006). In a similar way, the PLOE Framework aims to help those who design and deliver professional learning to teachers, to become more aware of, and sensitive to, learning from the teachers' point of view. Throughout the discussion that follows I will draw on the assumptions and principles of Variation Theory to explain its relevance to the PLOE Framework for supporting Australian K-12 STEM teachers' professional learning through Open Education. Combined with the phenomenographic findings of this study, I will show what it takes for individual teachers to experience PLOE in certain ways. To begin, the theoretical foundations of the PLOE Framework are presented with reference to three key concepts: 'critical aspects', the 'object of learning', and 'learning'.

6.2.1. Foundations of the PLOE Framework

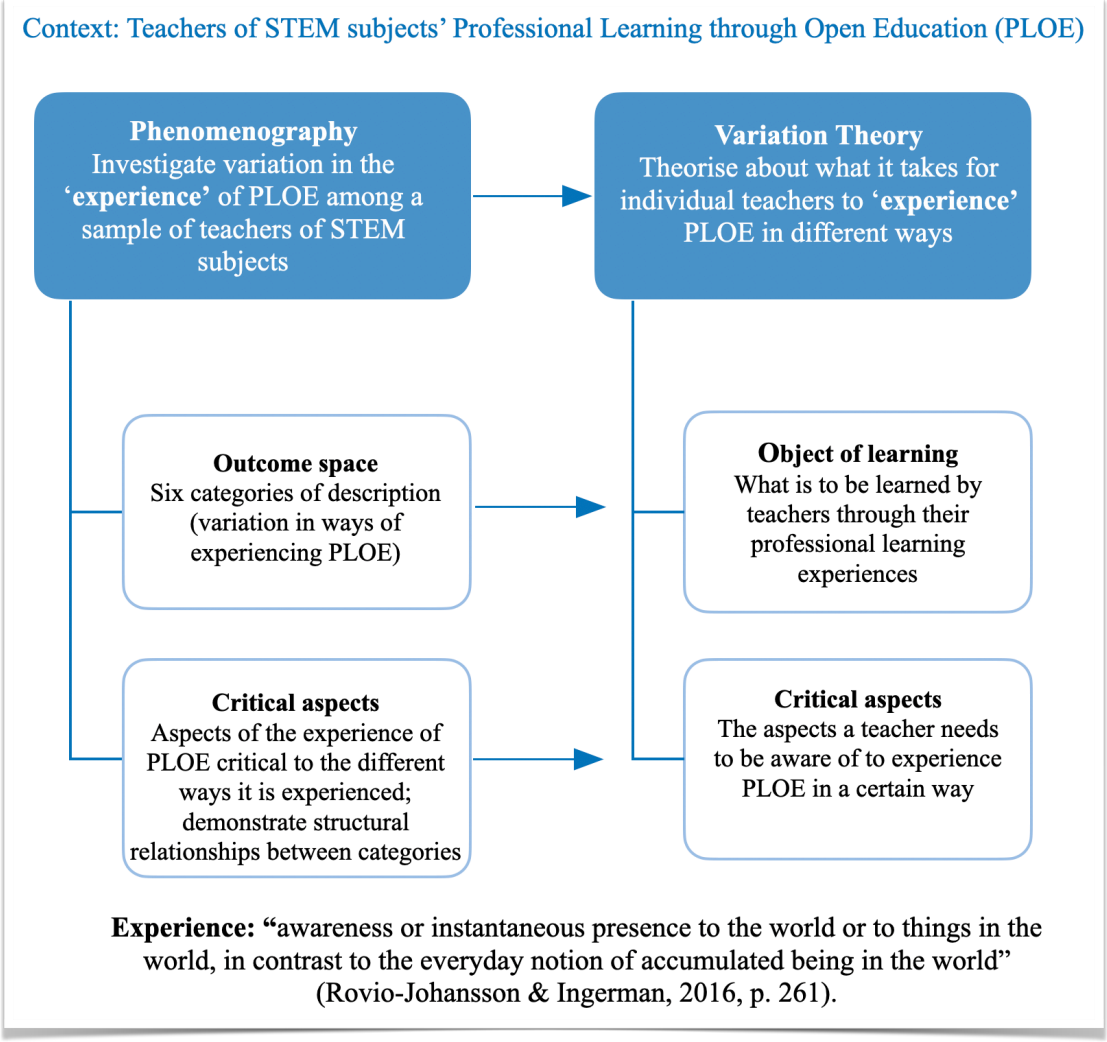
According to Rovio-Johansson and Ingerman (2016, p. 261), there is a clear relationship between phenomenography, Variation Theory, and Learning Studies:

> Phenomenography explores the qualitatively different ways in which people potentially "experience" certain phenomena they meet in their worlds, variation theory offers a framework for understanding what it takes to experience something in a certain way (or learn about it), and learning studies make use of that framework to design teaching for good learning results (Rovio-Johansson & Ingerman, 2016, p. 261).

One way these fields of research are connected is through the concept of "critical aspects" of learning (Pang & Ki, 2016, p. 334) which, through the lens of Variation Theory, is integrated with another concept, the "object of learning" (Marton, 2015, p. 22). Together, these two concepts constitute how learning is understood to occur in Variation Theory, and form the theoretical foundation and emphasis of the PLOE Framework, as illustrated in Figure 6.2 below.

Figure 6.2

Relationships Between the Concepts in Phenomenography and Variation Theory



The 'object of learning' refers to "what is to be learned" by teachers through their professional learning experiences (Marton & Pang, 2013, p. 26). It means more than learning content, or achieving certain learning objectives that may be expected of teachers by the end of a professional learning event. 'What is to be learned' refers to the 'aspects' a teacher needs to become aware of in order to experience PLOE in a certain way. For example, for a teacher to experience PLOE in a similar way to 'Building on the ideas of others' (Category 4 in the outcome space), he/she needs to be aware of the 'aspects' that characterise Category 4. He/she needs to discern (notice) that it is a creative, communal experience that involves other people's learning as well as their own; includes the practices of repurposing and re-sharing resources; and a culture of openness, which includes open licensing and attribution of each

other's work. 'Aspects' missing from a teacher's awareness that prevent him/her from experiencing PLOE in a similar way to Category 4 are the 'critical aspects' associated with 'what is to be learned' for that teacher during a professional learning event. From this example it can be seen that 'critical aspects', as seen through the lens of Variation Theory, are different to how they are conceptualised in phenomenography; they are related to the structure of an individual's awareness, in contrast to the structure of categories of description in the phenomenographic outcome space. Thus, a change in a teacher's "structure of awareness" (Pang, 2014, p. 5950), or "an expansion in awareness" (Akerlind, 2015, p. 6) is seen as learning in the PLOE framework. Learning also means change in a teacher's "capability" (Pang, 2003, p. 153) to experience PLOE in a certain way.

Generally, the terms used here to conceptualise learning all refer to "learning through discernment" (Lo, 2012, p. 142); that is, learning to discern certain 'critical aspects'. The kind of learning promoted by the PLOE Framework is for individual teachers to expand their awareness of the experience of PLOE by developing the capability to discern (notice) other, or more, aspects of this phenomenon. Therefore, anyone helping teachers to learn this way needs to prioritise 'what is to be learned' (the object of learning) (Marton, 2015), over whether teachers are arranged in groups or communities, whether content is delivered via workshops, seminars or conferences, or if the event occurs face-to-face, in the workplace, or via digital technologies. Even so, it is recognised in the professional learning literature that activities provided and directed by others may, or may not, lead to teachers' learning (Beswick et al., 2016; Bobis et al., 2020). This can be understood through the lens of the Variation Theory of learning, that what is "intended" for teachers to learn, "enacted" by whoever delivers the professional learning, and actually "lived" by teachers during professional learning events, are not the same (Marton, 2015, p. 114). The following section examines the 'how' of the PLOE Framework through pedagogical considerations.

6.2.2. Planning and Pedagogy

My original argument for conducting this study is that people involved in the teaching profession, and in teachers' professional learning, need to understand more about professional learning from the perspective of teachers. Since the perspectives of teachers influence what they do in the classroom, and teachers influence student learning (Education Council, 2018a; Muijs et al., 2014; Pajares, 1992), it was important to explore and understand the views

teachers have about their experiences of professional learning. Experiences of PLOE were interpreted to be meaningful by teachers, which included having a positive influence on their actions in the classroom, and their students' learning. Therefore, this research further supports the well recognised link between the perspectives of teachers, and their classroom practice (Pajares, 1992). If teachers leave their professional learning events "wishing those designing them would make them more applicable to the ever-increasing challenges they face every day in their classrooms" (Timperley, 2012, p. 40), then what is 'intended' for teachers to learn is not aligned with their 'lived' experience.

Teachers' negative perceptions may be attributed to any number of factors, such as time limitations, presenter skills, lack of specificity or relevance, and/or not being personalised to individual needs (Cole, 2012). To help align 'intended' learning with teachers' 'lived' experience of professional learning, the different experiences of individual teachers, and the contexts within which they work, need to be taken into account (Beswick et al., 2016; Desimone, 2018). Therefore, teachers should have an input into the learning they need (Darling-Hammond et al., 2017). Professional learning will be more effective if teachers' needs are identified, understood, and taken into consideration when learning experiences are designed and implemented (Darling-Hammond et al., 2017).

The PLOE Framework incorporates the perspectives and needs of teachers through different sources of information. The following section describes the sources from which information is used to inform decisions about the content of teachers' professional learning.

Sources of Information to Inform Learning Design. For designers and consultants to focus on 'what is to be learned' when planning for, making decisions about, and facilitating professional learning events, they need to build upon two important sources of information (Lo, 2012; Pang & Marton, 2013). Firstly, the phenomenographic findings are a useful resource to help others learn how to experience phenomena in certain ways (Bowden & Marton, 2003; Marton & Pang, 2013). The phenomenographic findings from this study are derived from the lived experiences of a group of teachers similar to those the PLOE framework aims to support. Therefore, they are a useful source of information to be integrated into the PLOE Framework with respect to 'what is to be learned'. Secondly, as explained above, learning to discern (notice) certain 'critical aspects' is influenced by many things, one of which is the learner's previous experience of the phenomenon they are learning

about (Holmqvist & Selin, 2019). Teachers will therefore bring to professional learning events their prior experiences of learning on the Internet, along with their knowledge of, and different perspectives about, learning this way. This constitutes the second piece of information that learning designers must drawn on. A pre-event questionnaire is one way to elicit information about how teachers already experience professional learning on the Internet.

It is important to note that the PLOE Framework does not recommend specific learning activities based on this information about the object of learning, and the teachers' existing ways of experiencing the phenomenon. It does, however, recommend a strategy for the design and delivery of activities that should be contextualised to different professional learning situations, which can be referred to as facilitating the learner's exposure to variation. This strategy is outlined in the following section.

6.2.3. PLOE Framework: Learning as Experiencing Variation

To discern and focus on 'what is to be learned' teachers need to "experience variation" (Pang, 2014, p. 596). In Learning Studies 'variation' is used specifically to "design teaching for good learning results" (Rovio-Johansson & Ingerman, 2016, p. 261). In the context of the PLOE Framework, 'variation' refers to a broad strategy that can be used to bring about teachers' learning. This strategy begins by drawing teachers' attention to the 'whole' experience of PLOE, then continues in a sequence of contrast, generalisation, separation, and fusion (Marton, 2015):

1. **The 'whole': what the experience of PLOE actually is**. The purpose of this step is to help teachers discern (notice) the 'whole' phenomenon of the experience of PLOE. The meaning of a phenomenon arises through learning what it is (Marton, 2015). For example, use the outcome space to bring to the attention of teachers a situation where PLOE may be experienced in a relevant, meaningful way in their particular context.
2. **Contrast: what the experience of PLOE is not.** This step introduces variation in approaches to professional learning, where meaning arises through "learning what it is not" (Pang, 2014, p. 597). It helps teachers to discern the difference between the experience of PLOE, and other approaches to professional learning. For example, compare an experience of PLOE from the outcome space to other ways

teachers experience professional learning, in their particular contexts. They may notice that the 'practices' they engage in to learn, are different.

3. **Generalise: different ways to experience PLOE.** This step introduces variation of the same phenomenon. For example:
    (a) Use information elicited from teachers through a pre-event questionnaire about their prior experiences and perspectives of learning on the Internet/ Web. Through this information, and in-event discussions, it should be evident that teachers have different experiences and perspectives of the same approach to learning. To broaden their awareness, give teachers the opportunity to learn how others experience learning on the Internet/Web. This may also encourage teachers to "become more tolerant and inclusive of others' views" (Lo, 2012, p. 104).
    (b) The key findings of this phenomenographic study are another useful resource for this step. Use the categories of description to help teachers notice the ways in which different experiences of PLOE are similar, and different. For example, take the aspect of 'practices' identified through contrast in Step 2. This aspect is found in (generalised across) each of the six different categories. Help teachers to recognise that the 'practices' are different in each category. They should then be able to identify what they need to learn in order to experience PLOE in more complex, meaningful ways.
4. **Separate: deconstructing a 'whole' experience of PLOE into its 'parts'.** This step introduces variation of 'parts' that constitute a phenomenon. It further differentiates the experience of PLOE by separating the 'whole' into its parts. Meaning stems from knowing what the 'parts' belong to. For example, help teachers to discern the different 'parts' of one way of experiencing PLOE. Separate the aspects of one category, one at a time, to bring out teachers' awareness of the different 'parts', and how to tell them apart.
5. **Fuse: reconstructing the 'parts' back into a 'whole' experience of PLOE.** The purpose of this final step is to help teachers discern the how aspects are related to each other, and to the 'whole' experience of PLOE. For example, continue with

Step 4, and help teachers see how the aspects come together to form the 'whole' experience again. Describe a scenario that simultaneously brings together the aspects of a particular category similar to how the 'whole' phenomenon would be experienced in their unique, everyday contexts. Meaning stems from knowing how PLOE can be experienced in their real-world contexts.

Table 6.1. summarises the foundations of the PLOE Framework outlined above.

Table 6.1

The Foundations of the PLOE Framework

Foundations of the PLOE Framework	
Learning	Discernment Object of learning Critical aspects
Sources of information	Phenomenographic findings Pre-event questionnaire In-event discussions Feedback and reflection
Sensitivity to teachers	Prior experiences and knowledge Needs: relevant, meaningful, contextual Perspectives
Variation sequence	The 'whole' Contrast Generalise Separate Fuse

This section presents the essence of the PLOE Framework in response to RQ3: How can the new knowledge gained from RQ1 and RQ2 be used to design professional learning experiences for Australian teachers involved in STEM education? In the next section I will build upon, and enhance, this framework by incorporating the elements of effective professional learning. These elements are reported in the K-12 teachers' professional learning literature, and were reviewed in Chapter 2.

6.3. The PLOE Framework and Elements of Effective Professional Learning

In the K-12 teachers' professional learning literature there is consensus that professional learning activities are effective if they include most of these design elements: are content focused; incorporate active learning; support collaboration; use models of effective practice; provide coaching and expert support; offer feedback and reflection; and are of sustained duration (Darling-Hammond et al., 2017). The following sections briefly describe each of these elements, highlight examples found in different experiences of PLOE, then link them as design elements to the PLOE Framework.

Content Focussed. Content focussed professional learning gives teachers the opportunity to apply new ideas, and knowledge of their subjects, in the context of their own classrooms. This approach to professional learning is perceived by teachers to be most effective (ACER, n.d.-b; Thomson & Hillman, 2019). With respect to informal professional learning, teachers are particularly motivated to acquire knowledge of subjects, pedagogy and skills that are "practical, relevant, useful, and meaningful" for classroom use (Kyndt et al., 2016, p. 1130), a finding which is substantiated in this research. For example, in Category 2 ("Filling knowledge gaps") the focus of teachers' awareness is on finding STEM-related content. As the experience of PLOE becomes more complex, awareness expands to repurposing and transforming content in Category 4 ("Building on the ideas of others") and to "Learning while teaching" in Category 5. The experience of PLOE in Category 5 reflects the "context specific, job embedded, and content based" learning reported in the literature on effective professional learning (Darling-Hammond et al., 2017, p. 7). What is new knowledge is that teachers access the content they need for teaching informally via the open Web, in 'real time' during the formal situation of teaching. The PLOE Framework therefore includes the design of professional learning experiences that target the specific content for teaching integrated STEM programs relevant to these just-in-time classroom teaching and learning contexts.

Active Learning. Active learning occurs when teachers participate in the practices they are learning about and plan to use in their classrooms (Darling-Hammond et al., 2017). As a self-directed approach to professional learning, this element is fundamental to the experiences of PLOE reflected in the outcome space, where all experiences of PLOE described by teachers are 'active'. They all include teachers participating in certain

‘practices’. In fact, in Category 5, teachers participate in the ‘practices’ they are learning about, while teaching. People who design and deliver professional learning for teachers of STEM subjects based on the PLOE Framework should incorporate active learning experiences for teachers. For example, if a teacher has identified that he/she needs to learn how to use Twitter hashtags to find contemporary scientific information, the person delivering professional learning could bring this practice into their awareness via a demonstration. The teacher could practice in the professional learning environment, and try it out ‘in practice’ whilst teaching.

Collaboration. Active learning often includes collaboration with other people (Darling-Hammond et al., 2017). Effective professional learning “creates space for teachers to share ideas and collaborate in their learning” (Darling-Hammond et al., 2017, p. 7). In my findings, the presence of other people in the teacher’s experience of PLOE first appears in the experience of learning in Category 3 (“Being a part of something much bigger”) (See Figure 6.1). The focus of awareness in this category is on learning about STEM education in the interactive, social, digital learning environment. This awareness of ‘collaboration’ expands in Category 4 to encompass a focus on creative collaboration with others (“Building on the ideas of others”), further expanding in Category 5 to include the pedagogical applications of collaboration (“Learning while teaching”). Based on these experiences, the PLOE Framework incorporates collaboration into its design – for example, teachers sharing ideas with others on Twitter, or collaborating on a lesson plan via a shared, open document.

Models of Effective Practice. Effective professional learning should also include the use of models of effective teaching practice (Darling-Hammond et al., 2017). On their website, the Australian Institute for Teaching and School Leadership (AITSL, n.d.) provides ‘models of effective practice' for Australian teachers. Illustrations of ‘effective’ practice (in the form of instructional videos) are linked to the Australian Professional Standards for Teachers (AITSL, n.d.). However, what AITSL views as ‘effective practice’ is not necessarily what teachers find and share on the Web during their experiences of PLOE. Therefore, this design element is not integral to the PLOE Framework which is based on what is relevant, meaningful and contextual from the perspective of teachers themselves.

Expertise. Effective professional learning includes the support of experts (Darling-Hammond et al., 2017). An **'expert'** can be many things, for example, a coach, mentor, specialist teacher, university-based scientist and so on. Generally, they facilitate teachers' learning through sharing their expertise of certain content knowledge, facilitating discussions, and helping teachers implement new pedagogical practices (Darling-Hammond et al., 2017). Experiences of PLOE described by participants in this study include the presence of 'experts' who contribute to their learning in different ways. For example, in the experience of PLOE in Category 3 ("Being part of something much bigger") experts share "international perspectives on issues" (Teacher 11). Importantly, access to experts is not limited to the workplace context. For example, representing the experience of PLOE in Category 4 ("Building on the ideas of others"), Teacher 14 noted "I met up with some game programmers, I met up with some engineers" and, in Category 5 ("Learning while teaching"), Teacher 1 drew on the expertise of an expert on the open Web – "one of my friends, LL, whose very good at Scratch, who works on the world museum global projects in Scratch" – while she was teaching.

The PLOE Framework incorporates this design element in different ways to help teachers implement new pedagogical practices. Firstly, scaffolded opportunities for connecting with other people, or "experts" on the open Web can be included in professional learning programs to support/help teachers to broaden their awareness of the 'things' and 'practices' they need to learn. As the complexity of the experience of PLOE expands, teachers themselves become "experts" as they build on the ideas of others to create new knowledge (Category 4), use technologies to connect, expertly, with others as part of their repertoire of STEM pedagogies (Category 5), and even to provide peer feedback to support the experience of PLOE for others as personal and professional change (Category 6).

Feedback and reflection. Along with expertise, effective professional learning includes feedback and reflection, two elements common to theories and practices of adult learning (Brookfield, 2005; Darling-Hammond et al., 2017) which are incorporated into the PLOE Framework. The experiences of PLOE reflected in the outcome space support reflection, generate feedback from others, and bring about changes in teachers and their practices. For example, in Category 4 ("Building on the ideas of others"), Teacher 14 commented "For me, actually sharing that out there, and taking on the chin some of the

criticism, I had the feedback I needed to have which meant that my project could move a lot faster". Also, reflecting on what brings about personal and professional change is focal in teachers' awareness in the experience of PLOE described in Category 6 ("Personal and professional change"). To support meaningful personal and professional change to occur, teachers can be supported in their learning to reflect on their assumptions and practices, and to elicit feedback from others to inform and challenge their thinking, as described in the previous section.

Sustained duration. Finally, effective professional learning needs to be sustained. Sustained duration is a recommended design feature for effective professional learning, yet teachers often experience "short-term courses or single workshops" (Gomez Zaccarelli, et al., 2018, p. 30). Sustained professional learning is needed for teachers to develop their understanding of, and capability to, teach interdisciplinary STEM pedagogies (Fraser et al., 2019, p. 23). Although the experiences of PLOE described in this study did not arise through formal, long-term courses, teachers' professional learning was meaningful, and, over time, led to personal and professional change. In Category 1 ("Reclaiming autonomy"), the focus of teachers' awareness was on their opportunity for, and flexibility of, professional learning on the open Web. Through the experience of PLOE, teachers have the opportunity to take control of their own learning, and to learn any time they are willing and able to (assuming there is a reliable internet connection). Therefore, not only is PLOE a sustainable approach to professional learning for Australian teachers of STEM subjects, it is also promoted through the PLOE Framework as being life-long. As is the case for other professionals, there is an expectation that teachers will continue to learn through their working lives (Thomson & Hillman, 2019; Webster-Wright, 2009). In fact, in the broader context of adult education, life-long learning "through informal and self-directed learning is no longer a luxury but a requirement" (Lin & Cranton, 2015, p. 101). Therefore, experiences of PLOE, based on the PLOE Framework, can help teachers to fulfil this professional requirement.

The key findings of this study show that six elements of effective professional learning are present in the different ways PLOE is experienced by Australian teachers of STEM subjects. Based on this new knowledge, users of the PLOE Framework are encouraged to incorporate these elements into the design and delivery of professional learning. Activities need to focus on content; engage teachers in active learning practices;

enable collaboration; connect teachers to experts; encourage feedback from others, and facilitate reflection; and promote sustained/ongoing professional learning on the open Web.

Thus far, the essence of the PLOE Framework outlines a theoretically grounded, pedagogical approach to teachers' professional learning. It also contributes to knowledge in the area of adult learning. Through the sequential approach to facilitating teachers' learning via exposure to variation, and discernment of critical aspects of awareness of PLOE, consultants can make meaningful, effective professional learning possible for teachers, and self-directed teachers can make meaningful, effective learning possible for themselves. However, the design features of effective professional learning are considered "necessary but not sufficient" to facilitate change in teachers' knowledge, practice, and/or student learning (Borko, 2019; Osborne et al., 2019, p. 1069). Similarly, the features of the PLOE framework outlined thus far can be applied to – but are not uniquely situated in – the digital domain, and are therefore considered 'necessary but not sufficient' to facilitate professional learning for Australian teachers of STEM subjects through Open Education. In the next section I present further design features to enhance teachers' learning in the complex environment of the open Web.

6.4. The PLOE Framework and Open Education

Following a review of the literature in Chapter 2, Open Education was interpreted as teachers having access to professional learning on the open Web through their 'practices' (Open Educational Practices), which includes their actions with educational content (Open Educational Resources). The open Web was conceptualised as the digital context for teachers' professional learning, composed of Web tools, platforms, resources, people, and the social aspect of culture. Learning in the digital, networked environment of the open Web was described as "connectivist" in nature (Siemens, 2005, p. 5), and new knowledge about STEM education was assumed to emerge from the connections teachers made in their networks. Networks from which knowledge is most likely to emerge have the design characteristics of autonomy, diversity, openness and interactivity (Downes, 2012; Kop & Hill, 2008). In the next section these characteristics are described, related to my findings, and then linked to the PLOE Framework.

6.4.1. Characteristics of Effective Networks

Autonomy. Autonomy refers to learners managing their own connections and interactions in a network, and choosing what, how, and with whom to learn (Downes, 2020). Learner autonomy is a characteristic of the experience of PLOE, in fact, it gives meaning to the experience described in Category 1: "Reclaiming autonomy". The range of 'practices' identified in different experiences of PLOE shows that teachers learn autonomously in different ways, ranging from simple to more complex. For example, learning in networks on the Web may involve making decisions over what, when, where, how and why to learn something (as in Category 1), or collaborating with other teachers to create a resource, as is the case in Category 4 ("Building on the ideas of others"). Designers and consultants using the PLOE Framework need to support and foster teacher autonomy and decision making, rather than expecting teachers to experience their professional learning in specified ways. For example, in Category 6 ("Personal and professional change"), the Web was described as a public place that can induce feelings of insecurity. Therefore, teachers should not be obliged to be social, in public, on social media. They may prefer to 'lurk' while learning, as evidenced in Category 6. This example illustrates a point made in Section 6.2, that the PLOE framework, based on the "Variation Theory (of Learning)" (Marton & Pang, 2013, p. 24), is designed to help professional learning providers to become more aware of, and sensitive to, learning from the teachers' point of view (Pang, 2006).

Diversity. Diversity refers to learners interacting with different people in terms of "gender, race, culture and socio-economic status" (Tschofen & Mackness, 2012, p. 134), being exposed to diverse opinions and perspectives (Siemens, 2005; Tschofen & Mackness, 2012), and using of different tools and resources to learn (Downes, 2009, 2017). This characteristic is seen throughout my findings. For example, teachers' awareness of diversity of people and perspectives in their learning environment on the Web emerged in Category 3 ("Being part of something bigger"). This includes the 'ugly' and unprofessional side of social media, as exemplified in the ways of experiencing PLOE in Category 3 described in Chapter 5. Diversity of the ideas of others is central to the experience described in Category 4 ("Building on the ideas of others"), and awareness of diversity of people from different education sectors across Australia is present in Category 5 ("Learning while teaching"). In

Category 6 ("Personal and professional change"), awareness of the diverse cultural backgrounds of people around the globe emerged.

With respect to resources, despite the abundance, diversity and benefits of OER available on the Web, people across different education sectors range from being aware of OER, and open licenses, to having some awareness of one or the other, to having limited awareness of both (de los Arcos et al., 2016; Weller, 2020b). Awareness of OER, or open licenses, first emerges in a limited way in Category 2 ("Filling knowledge gaps"), in the form of open licenses. The Category 3 ("Being part of something bigger") experience is similar, although the culture of openness is more altruistic and democratic. Teachers share 'what works' for the benefit of others, although there is evidence of sharing, without attribution to the creator. Category 4 ("Building on the ideas of others"), describes the 'practice' of creating OERs, and using open licenses. The characteristic of diversity is integral for the PLOE Framework, in that teachers will be encouraged and supported to create diverse learning environments on the Web, through the connections they make, and the Web tools they use.

Interactivity and connectedness. Interactivity and connectedness is a characteristic that indicates how knowledge in the network is produced. An assumption is that knowledge is not centralised in one person then spread throughout the network, rather, knowledge emerges from the "interactions among people" (Downes, 2012, p. 99, 2017). Teachers learning on the Web do not experience professional learning through a centralised learning management system. The Category 3 ("Being part of something bigger") experience, for example, describes awareness of knowledge, expertise and resources not being limited to the one source, that is, the workplace (school) context. Learning is experienced as networked, and connected, well beyond the school walls. In Category 4 ("Building on the ideas of others"), awareness broadens to teachers themselves contributing to knowledge creation and dissemination, through their interactions with the ideas of other people. As with diversity, this characteristic of interactivity and connectedness is integral to the PLOE Framework. The digital learning environment teachers create for themselves will facilitate their connection to, and interaction with people, ideas, and resources. It is assumed that new knowledge about STEM education will emerge from the many sources of information teachers connect to. Teachers' ability "see connections between fields, ideas, and concepts" (Siemens, 2005, p. 6)

is a fundamental skill of connectivist learning. It is also necessary for interdisciplinary STEM education.

Openness. Openness refers to the freedom and ease of people entering and leaving a network (or online community) (Downes, 2017; Tschofen & Mackness, 2012). It also refers to the flow of information, ideas and artefacts into, and out of, the network/community (Downes, 2012; Tschofen & Mackness, 2012). The experience of PLOE described in Category 2 ("Filling knowledge gaps") showed awareness of websites being 'open' in contrast to 'firewalled'. There was understanding of potential barriers to their participation in learning on the open Web. Teachers also engaged in a range of open 'practices', during their experiences of PLOE. For example, the Category 3 ("Being part of something bigger") experience described teachers communicating with others on social media. To do so, teachers experienced developing their open, online identities. This sign of openness in the practices of teachers preceded the creative practices of OER/educational resources evident in the experience of PLOE described in Category 4 ("Building on the ideas of others"). This finding supports Cronin & MacLaren's (2018) comment that "the first sign of openness in educational practice" (p. 131) may not necessarily include the creative practices of 'doing' something with OER. Regarding implications for the PLOE Framework, teachers need to be aware of certain features of 'openness', such as communicating on the open Web, and developing their online identities, before engaging in the more 'complex' activities reflected in the experience of PLOE in Category 4.

What is interesting about the outcome space is how metaphors are used to communicate experience of the open Web as a learning context. Teachers' understanding of openness is described differently in each category, ranging from a 'thing' (Category 1); a 'place' (Categories 2, 4, 6); a 'world' (Category 3); a journey, a flow, feed or stream of information (Category 3); a network and/or learning community (Categories 3, 4). People use metaphors to express their "understandings of reality" (Jensen, 2006, p. 36). Therefore, these metaphors have a pedagogical role in the PLOE Framework, and can be used to help teachers understand the openness of their learning environment in different ways.

Overall, there is evidence in the outcome space of these characteristics of effective knowledge creation in networks. Based on these characteristics, users of the PLOE Framework need to ensure that professional learning events are designed to: support teachers'

autonomy, foster diversity; promote interactivity; and remove barriers to openness. The next section considers a type of network commonly described in the K-12 teachers' professional learning literature, the Personal/Professional Learning Network (PLN).

6.4.2. Professional Learning Networks

PLNs are defined as "uniquely personalized, complex systems of interactions consisting of people, resources, and digital tools that support ongoing learning and professional growth" (Trust et al., 2016, p. 28). This definition of PLNs overlaps with the phenomenon of PLOE, presented in Chapter 2 as being bounded by the concepts of professional learning, the open Web, and Open Education. Research shows that teachers already manage, and self-direct, their professional learning in online environments (Bobis et al., 2020; Kelly, 2019), and use their PLNs to participate in professional learning in different ways (Carpenter et al., 2020a; Lantz-Andersson et al., 2018; Prestridge, 2019). This includes collaborating with colleagues (Prestridge et al., 2019), and engaging in "reflective cycles" of using and creating content/resources, experimenting with new ideas in the workplace, and feeding new knowledge back into their PLNs (Prestridge, 2019, p. 18). This literature corresponds to the experiences of PLOE described in Categories 1-4 of the outcome space.

Additionally, in the PLN literature there is little reference to content/resources as OER, open licensing, the practices associated with the creation and use of OER, and the term OEP is rarely used. However, there are signs of openness in the online practices of teachers in their PLNs. There is recognition of increased access to abundant resources (Prestridge, 2019), and to the availability of resource repositories for teachers to connect to (Oddone et al., 2019; Prestridge et al., 2019). There is also mention of sharing, consuming, generating (Prestridge, 2019), and remixing (Oddone et al., 2019) content/resources. The term participatory culture is widely used, yet there is limited discussion of the values underpinning this shared culture and practice. This literature does, however, raise awareness of the challenges teachers face when creating and maintaining their PLNs in digital environments (Krutka et al., 2017). Similarly, the outcome space of this study revealed that experiences of meaningful, self-directed, informal professional learning in the complex, networked environment of the open Web comes with certain problems and barriers. The next section

briefly discusses certain problems and barriers, then links this component to the PLOE Framework.

Based on the overlapping conceptualisations of PLOE and PLNs this study makes a contribution to PLN research through the PLOE Framework. It also meets the recommend the need for "complex frameworks and models to understand and examine how educators engage with their PLNs to improve their practice" (Trust & Prestridge, 2021, p. 9).

6.4.3. Digital Literacies

The contemporary culture of learning on the open Web has implications for whether the PLOE Framework will enable teachers to experience meaningful professional learning. The experience of PLOE is associated with a range of problems and barriers to learning, described as technical and/or personal. Technical issues range from experiencing problems with the internet (Category 1); having file compatibility problems, and issues with the quality of information and global time zones (Category 2); and blocked websites (Category 5). Personal problems and barriers range from experiencing information overload and wasting time (Category 2); the anti-social and unprofessional side of social media (Category 3); language barriers and student discontent (Category 5); and being aware of one's own feelings and behaviour (Category 6). Teachers also judge/validate the authenticity, quality, relevance, and credibility of the information they find (Category 2); and the authenticity and credibility of other people (Category 3). These features indicate that to learn in the complex, networked environment of the open Web teachers need a range of digital capabilities (Fournier et al., 2019; Siemens et al., 2020). These findings are also supported by the Open Education literature reviewed in Chapter 2.

There is an abundance of information on the Web that needs to be filtered and managed (Fournier et al., 2019). Some will be important for teachers to learn about, and/or it may be harmful, false and/or inaccurate (misinformation), sometimes deliberately so (disinformation) (Jenkins et al., 2016; Weller, 2020b; Siemens et al., 2020). Therefore, teachers need to apply the connectivist skill of evaluating "the worthiness of learning something" (Siemens, 2005, p. 2). Information and media literacies are needed to validate information and its sources (Fournier et al., 2019), and to maintain the quality of the resources used (Carpenter, et al., 2020b). People also experience offensive behaviour on the Web, such as public shaming, trolling, harassment, and hate speech (Jenkins, et al., 2016;

Weller, 2020b). Therefore, teachers also need the skills to negotiate "contradictory opinions" (Siemens et al., 2020, p. 111), and anti-social behaviour.

These "challenges and risks" (Tur et al., 2020) of learning on the open Web need to be raised in teachers' awareness. Teachers may need support to create their online identities, balance their personal and professional identities, and negotiate their perspectives regarding making public and/or private contributions on the Web. Therefore, the PLOE Framework incorporates the development of teachers' digital capabilities. For example, components of the "Jisc digital capabilities framework" (Jisc, 2019, p.2) can be incorporated into the design and delivery of professional learning events (Jisc, 2019, p.2).

6.5. Bringing Together the PLOE Framework

For well designed, meaningful professional learning in digital networks the PLOE Framework is underpinned by the Variation Theory of learning, incorporates features of effective professional learning, and effective digital networks. It also recommends that teachers are made aware of the digital capabilities needed for learning in complex digital environments. One final consideration is how teachers' learning is conceptualised by providers of professional learning. To understand how learning occurs, metaphors were used as an organising framework to review of the literature on K-12 teachers' professional learning in Chapter 2. This review revealed that learning is often conceptualised as acquisition, participation, and knowledge creation. There is evidence of all three metaphors in the different, meaningful ways PLOE was experienced by teachers in this study.

The acquisition metaphor assumes that teachers need updating because they are deficient in certain skills and knowledge (Boud & Hager, 2012; Forde & McMahon, 2019). In the experience of PLOE described in Category 2 ("Filling knowledge gaps"), the focus of teachers' awareness is on finding an acquiring useful information, and resources, to increase their knowledge of STEM education. The participation metaphor assumes that teachers participate in the cultural practices and activities of a community (for example, the cultural practices of a community/network on the open Web), and become more knowledgable through their activities (Borko, 2004; Sfard, 1998, 2009a). In Category 3 ("Being part of something much bigger") there is awareness of learning as participation in a social and interactive, digital learning environment. In the context of this study, the creation metaphor assumes that teachers create new knowledge during their social and cultural practices of

participating in professional learning activities. This metaphor is evident in Category 4 ("Building on the ideas of others"). With a focus of awareness of repurposing and transforming information and ideas, learning is experienced as a creative process. Therefore, all three ways of conceptualising learning are meaningful to teachers.

This finding needs to be taken into consideration by those who design and deliver professional learning to teachers via the PLOE Framework, and links back to the discussion of 'autonomy' in networks. The PLOE Framework is based on the "Variation Theory (of Learning)" (Marton & Pang, 2013, p. 24), and is designed to help professional learning providers to become more aware of, and sensitive to, learning from the teachers' point of view (Pang, 2006). There is not a fixed body of knowledge about the content and pedagogy of STEM education in the K-12 sector. Teachers need knowledge of their core subject areas, such as mathematics and science, knowledge of what constitutes an integrated STEM program, and the pedagogical knowledge of how to teach it. Therefore, 'acquiring' mathematics content knowledge through solo activities on the open Web may be meaningful for one teacher, whereas, to another 'participation' in ongoing, public debates about the nature of integrated STEM may be more meaningful. These different perspectives need to be respected and accommodated by professional learning providers. Table 6.2 below brings together the main features of the PLOE Framework.

Table 6.2

The PLOE Framework for Meaningful Professional Learning

Theoretical Foundation	Design Principles and Features	
	Principles	**Features**
1. Phenomenographic outcome space (empirical evidence: variation in teachers' experiences of PLOE) 2. Learning as discernment (Variation Theory) • Awareness of 'what is to be learned' (object of learning) • Critical aspects of awareness	Teachers' PLOE • occurs in digital networks • fosters a culture of *openness* • builds teachers' *digital literacies* and *capabilities* • is *content focused* • is learner-centred and learner-driven (learning is *active*, *autonomous*, and *sustained*) • is contextualised to different professional learning situations • can be situated in practice; has a positive influence on teachers' pedagogy and student learning • builds teachers' capability to experience PLOE in a certain way	Sources of information to inform learning design • Teachers' prior experiences and knowledge of PLOE (Pre-event questionnaire, in-event discussion) • Phenomenographic outcome space: variation in teachers' experiences of PLOE Variation sequence • The 'whole' • Contrast • Generalise • Separate • Fuse Provides • access to *experts* • opportunities for *interactivity, collaboration*, *feedback* and *reflection*

6.6. Recommended uses of the PLOE Framework

The PLOE Framework, and the phenomenographic findings incorporated within it, is evidence-based, and underpinned by a theory of learning. It presents an approach to professional learning that is based on the informal and meaningful experiences of teachers, and is sensitive to their point of view. Use of the Professional Learning through Open Education (PLOE) Framework is recommended for K-12 teachers' to self-direct their own professional learning; for others to design and deliver professional learning for teachers of

STEM subjects in K-12 schools; and for STEM Education Policy-makers to guide and support the professional learning of teachers.

6.6.1. Teachers' Self-assessment of their own Capabilities

As a foundational component of the PLOE Framework, the phenomenographic outcome space can be used by any teacher to compare their own capabilities against. This acknowledges teachers as autonomous learners who need to have a say in their own learning (adult learning theory). This is a way for teachers to ascertain what they are already aware of, and what they need to learn in order to experience PLOE in more complex, and meaningful ways. Teachers who wish to direct their own learning can use the five steps of experiencing variation described in Section 6.2.3. For example:

1. From the outcome space teachers can see what the 'whole' experience of PLOE actually is.
2. Through reflection, teachers can contrast their understanding of the experience of PLOE to other professional learning approaches they have experienced in the past.
3. Through exposure to variation of the experience of PLOE in the categories of description, teachers can familiarise themselves with the different ways PLOE is experienced by others, and identify what they need to learn in order to experience PLOE in more complex, and meaningful ways.
4. Learning is enhanced if teachers consider all of the critical aspects that constitute a particular way of experiencing PLOE.
5. Finally, a teacher's new way of experiencing PLOE will be more meaningful when applied in the real-world context of practice.

For the purpose of external "validation" (that is, demonstrating professional learning undertaken to renew their teacher registration), teachers can reference their capabilities, and new learning, against the Australian Professional Standards for Teachers to lodge with their registration authority. For example, in the context of STEM education, the educational resources they create and share, social media conversations, and blog posts, are all evidence of professional learning. Teachers can also map their capabilities to a published, capabilities framework, for example, the Jisc (2019) digital capabilities framework, and submit as evidence of professional learning.

6.6.2. Learning Designers and Consultants

Findings from this study can be used by providers to inform the design and evaluation of their professional learning programs for teachers of STEM subjects. The PLOE Framework provides a strategy for designers and consultants to use as heuristics for the planning and delivery of meaningful professional learning to teachers, as seen from the perspective of teachers themselves, as learners. By following the framework, designers can support teachers to work through the recommended sequence described in Section 6.2.3. In this way teachers can be guided through the different ways of experiencing PLOE identified in this study, thus exposed to variation and supported to discern the critical aspects that will bring about their learning. For example, my findings revealed that teachers sometimes experience PLOE as a way to not only top up their knowledge, but to create new knowledge/ new was of teaching STEM with other teachers. Both of these experiences are meaningful to teachers. A provider could use such information to design and/or evaluate their professional learning programs: to address the identified learning needs of teachers of STEM subjects in specific contexts; to see if their programs include meaningful activities for teachers to use the open Web to top up their knowledge of STEM ("content") as needed; and also to support them to drive innovation in their teaching practices in collaboration with their colleagues.

6.6.3. STEM Education Policy-makers

One of the purposes of the Australian education policy is to guide and support the professional learning of teachers. A component of the Government's agenda includes a range of *Inspiring all Australians in digital literacy and STEM* initiatives, introduced for the benefit of students and teachers (Australian Government, n.d.). Through these initiatives the Government seeks to increase the capacity of teachers, which is related to equipping teachers with the skills and confidence to facilitate quality teaching (Education Council, 2015). The PLOE Framework is one approach to supporting teachers in the long term integration of the Government's STEM initiatives into their teaching practice. This could be a powerful tool to address some of the needs of teachers' professional learning and development in STEM education.

6.7. Contributions of this Study to the Fields of STEM Education, Professional Learning and Open Education

Australian STEM education is a developing/emerging area of research (Anderson et al., 2020, p. 41; Fitzallen & Cooper, 2019), and researchers claim that more information is needed regarding how teachers can be supported as they adapt to teaching a more contemporary, and integrated STEM curriculum (Timms et al., 2018). Concerns were identified in the literature regarding the population of Australian teachers, particularly the availability of qualified teachers for STEM subject areas (Timms et al., 2018). There is an ongoing challenge to recruit, retain, and support teachers, particularly in regional and remote areas of Australia (Fraser et al., 2019). Once recruited, teachers may lack the confidence to teach in STEM subject areas (Rosicka, 2016); may be inexperienced and/or be expected to teach outside their specialist areas - known as “out of field teaching” (Fraser et al., 2019; Timms et al., 2018, p. 17; Weldon, 2016); and be expected to cope with issues of inequality in schools across Australia (Murphy et al., 2019, p. 126). Thus, teachers need support with resources and expertise (Fraser et al., 2019; Lowrie et al., 2017). They also need support to implement interdisciplinary STEM pedagogies (Anderson et al., 2020; Fraser et al., 2019), where emphasis is placed on the connections between STEM subject areas, and the application of knowledge to real-world problems that exist beyond the classroom (Rosicka, 2016; Taylor, 2018).

Throughout this chapter I have argued that experiences of PLOE can support teachers as they learn about interdisciplinary STEM education, albeit in different ways. For example, teachers in different schools across Australia, including regional and remote areas, access professional learning on the open Web. They are represented by participants in this study. Initially, teachers support themselves by "Reclaiming autonomy" over their professional learning in Category 1. They have access to an abundance of content/OER to fill in their knowledge gaps, as experienced in Category 2, and can access ongoing support from experts through their connectivity in networks, as experienced in Category 3 (“Being part of something much bigger"). There is evidence of pedagogical change towards integrated STEM described in the experiences of Categories 4, 5 and 6. Teachers made connections in their networks that cut across traditional curriculum boundaries into the context of real-world problems external to the classroom. There is also evidence of increased confidence to teach in

STEM subject that emerged Category 6 ("Personal and professional change"). Therefore, this study contributes to the field of professional learning in the context of STEM education and Australian teachers' work. It shows that, from the perspective of teachers who teach in the area of STEM education, professional learning can be more applicable to the changes and challenges teachers face in in the workplace. In difficult times, such as this caused by the coronavirus pandemic, professional learning through Open Education (PLOE) could reveal new approaches to professional learning in all areas of Australia's education and training sector, and in other disciplinary areas.

This research also makes an important contribution to the limited body of knowledge about Open Education in the K-12 sector. Open Education, as a vehicle for professional learning, provides a strategy for teachers to overcome the 'resources' barrier to implementing professional learning in the classroom. The PLOE Framework can be used for 'content focused' professional learning experiences related to the Open Educational Practices for OER creation and use. Learning about Open Textbooks may also help to overcome the resources barrier, particularly in relation to cost. However, to utilise the PLOE Framework in the classroom context, this research shows there may be barriers to teachers' participation on the open Web. Firstly, teachers in this study revealed problems and barriers related to technology use in their schools. The technical infrastructure of schools may need updating, including teachers having access to reliable internet connections. This is particularly important for teachers working in isolated and disadvantaged schools. Secondly, to enable teachers' autonomy over their professional learning, when it occurs while they are teaching, school policies related to teachers' use of social media, and OER/Open Textbooks, and intellectual property may need updating. This is also important to facilitate teachers' and students' connections to experts, community and industry for interdisciplinary STEM projects.

Another contribution to the field of Open Education this study makes is knowledge of an emerging 'STEM culture' and scholarship. Real-world examples of how OE is experienced by teachers for professional learning show a developing "culture of integrated STEM", an aspect of which is having access to resources relevant to their context (Fraser et al., 2019, p. 21). I would argue that another aspect of 'STEM culture' is teachers going public, sharing their practice on the open Web, opening it up to critique and feedback from peers, and making it accessible for other teachers to use. This form of inquiry into practice,

through a “disciplinary community”, is seen as a form of scholarship (Shulman, 2011, p. 4). By going public on the open Web teachers hold themselves accountable for their actions online, and their practice in the classroom. Knowledge is captured, made visible, shared, and preserved as an “artefact of scholarship” (Shulman, 2016, p. 24). This perspective on knowledge could underpin future development of OEP and OER in the K-12 sector and beyond.

6.8. Recommendations for Further Research

A direct extension of this study would be to conduct phenomenographic research into K-12 teachers’ experiences of specific phenomena related to PLOE, for example, OER, OEP, PLNs, digital literacies, and so on. To build a phenomenographic knowledge base of K-12 teachers experiences of professional learning, from their perspective, would be valuable addition to the professional learning literature. Another direction to take would be to test the PLOE framework, via a professional learning intervention, on a broader population of teachers. Researchers could use observations, interviews, and/or a questionnaire to ascertain how this framework is put into practice, and its value to teachers in terms of meaning and pedagogical change. Research findings can be used to develop and refine the PLOE Framework. This is one approach to meet the recommendation from researchers that future directions for research in the area of teacher education should “focus on the development of robust and empirically tested frameworks to support the professional learning of teachers tasked with developing integrated STEM curriculum” (Anderson et al., 2020, p. 45).

In the professional learning literature, the reported impact of professional learning on student learning ranges from teachers having a “positive influence” (Guskey, 2017, p. 33), to producing measurable improvement in student outcomes (AITSLa, 2012). My study did not address the latter, but experiences of PLOE described in Categories 5 (“Learning while teaching”) and 6 (“Personal and professional change") do include positive influences on student learning, from the perspective of teachers. A future direction for research would be to empirically investigate any link between teachers’ experience of PLOE, and their students' learning.

6.9. Concluding Thoughts

I return to Taylor's (2015) pertinent question held in mind since reviewing the professional learning literature in Chapter 2: "How can we prepare science teachers with professional knowledge and skills for ensuring that teaching and curricula meet the global challenges of the 21st century….?" (p. 1079). When reflecting on this question I thought about a blog post of mine: Why do networks matter?

> Networks aren't about the tools and platforms you use, they will change as time passes and our communities grow. They are about connecting with others, developing relationships, supporting and mentoring, sharing, laughing, caring, encouraging and participating. Educators don't need to feel isolated in their busy workplaces where transient conversations occur on the way to class and professional development is difficult and expensive to organise. We don't need to reinvent the wheel and feel reluctant to ask for help. Our voices can be heard beyond the noisy and sometimes threatening atmosphere of the staff room. Social networks do matter.

It was important to conduct this research. There is much anecdotal evidence for teachers' professional learning on the Web, to which this study adds empirical evidence. Experiences of PLOE were found to be meaningful for a group of teachers who represent Australian K-12 teachers of STEM subject areas. The PLOE Framework is the key outcome of this study, and is presented as a new approach to facilitate similar teachers' ongoing professional learning about STEM education, through Open Education.

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APPENDICES

Appendix 1. Expression of Interest (EOI) Form

Do you teach STEM related subjects (such as science, technology, engineering, mathematics, design and ICT) in an Australian primary or secondary school? Do you use social media, free online resources and web tools for professional learning?

If you answered yes to these questions you are invited to participate in a research project investigating the practices and experiences of Australian primary and secondary teachers who use the open Web for self–directed, independent professional learning.

What's involved if you agree to participate?

- You will be asked to complete a 15 to 20 minute online survey, and
- You may be contacted to participate in a 60 minute, online interview at a time convenient for you

Your participation in this project is entirely voluntary and, if you do agree to participate, you can withdraw from the project at any time.

Penny Bentley, a PhD candidate at the University of Southern Queensland, is conducting this research. If you would like to participate in this project, or require further information, please leave your details below.

Name

Email

Please ask any questions you have about participating in this study.

Appendix 2. Online Survey

Open Educational Practices and Australian STEM Teachers' Professional Learning

Phase 1: Online Survey

Survey Instructions

Thank you for participating in this online survey that seeks to describe the practices of Australian STEM teachers who engage in professional learning on the open Web.

The survey comprises 26 questions and will take approximately 15 to 20 minutes to complete.

Australian primary and secondary teachers who teach in the areas of science, technology and mathematics are invited to complete this survey.

All responses will be anonymous and no personal identifying information will be collected, analysed and published. Only aggregated data will be reported.

Selecting the 'Submit' button at the conclusion of the survey is accepted as an indication of final consent to share details and participate in this project.

Your time and insights are appreciated, thank you very much for completing this survey.

Penny Bentley (Principal Investigator)
University of Southern Queensland
Email: penbentley58@gmail.com
Mobile: 0448 665 429

Part A: Professional Learning on the open Web

The following questions are designed to collect information about your professional learning practices on the open Web.

The Open Web refers to the global, public and unrestricted online platform anyone with an Internet connection can access. Please indicate how often you engage in professional learning on the open Web during these times.

	Never	Rarely	Sometimes	Often	A great deal
During school hours	○	○	○	○	○
Outside of school hours, during the week	○	○	○	○	○
Outside of school hours, during the weekend	○	○	○	○	○

Please indicate the importance, to you, of these aspects of professional learning on the open Web.

	Not at all important	Slightly important	Important	Moderately important	Very important
Anyone can engage in professional learning on the open Web	○	○	○	○	○
Professional learning is social	○	○	○	○	○
Professional learning is flexible (anytime)	○	○	○	○	○
Teachers have choice over what they learn	○	○	○	○	○
Professional learning involves a culture of sharing	○	○	○	○	○
Professional learning involves a					

culture of participation	○	○	○	○	○
Professional learning is collaborative	○	○	○	○	○
Professional learning is continuous	○	○	○	○	○

Please describe any other aspects of professional learning on the open Web you consider important.

What do you gain from self-directed professional learning on the open Web? Please select all responses that apply.

- ○ Access to current information about the subject/s I teach
- ○ Exposure to new ideas
- ○ Educational resources
- ○ Knowledge of new ways to teach my subject/s
- ○ New connections with Australian teachers
- ○ Connections to STEM professionals
- ○ Improved content knowledge
- ○ Global connections
- ○ Support from other teachers
- ○ Inspiration
- ○ Other (please elaborate)

What concerns do you have about using the open Web for your professional learning? Please select all responses that apply.

- ○ Privacy
- ○ Data security
- ○ Professional identity
- ○ Access at school

- ○ Information overload
- ○ Quality of resources
- ○ Other (please elaborate)

The open Web supports a professional learning culture of sharing. Please indicate how often you share the following:

	Never	Rarely	Sometimes	Often	A great deal
Resources I create	○	○	○	○	○
Resources I find	○	○	○	○	○
Ideas	○	○	○	○	○
Experiences	○	○	○	○	○
Processes (how I do things)	○	○	○	○	○

Please describe other ways you contribute to the professional learning culture of sharing on the open Web.

How often do you search for the following educational resources on the open Web?

	Never	Rarely	Sometimes	Often	A great deal
Images	○	○	○	○	○
Videos	○	○	○	○	○
Digital textbooks	○	○	○	○	○
Slide presentations	○	○	○	○	○
Games	○	○	○	○	○
Lesson plans	○	○	○	○	○
Tests	○	○	○	○	○
Course materials	○	○	○	○	○

Music	○	○	○	○	○

Please describe other educational resources you search for on the open Web.

Where do you search for educational resources on the open Web? Please select all responses that apply.

- ○ Google
- ○ YouTube
- ○ iTunes
- ○ SlideShare
- ○ Flickr
- ○ OER Commons
- ○ Wikimedia Commons
- ○ CC Search
- ○ Other (please list)

Please indicate the level of importance you give to each of these reasons for using educational resources from the open Web.

	Not at all Important	Slightly important	Important	Moderately important	Very important
To replace expensive textbooks	○	○	○	○	○
To find resources not previously available	○	○	○	○	○
To build upon the expertise of others	○	○	○	○	○
To meet the diverse needs of my students	○	○	○	○	○

To save money	○	○	○	○	○
To develop a STEM curriculum	○	○	○	○	○
To save time	○	○	○	○	○

Please describe any other reasons why you use educational resources from the open Web.

Educational resources found on the open Web are not always legal to use. If a resource is not in the public domain, it's creator should make explicit how the resource can be used. This is the role of a Creative Commons license.

Educational resources in the public domain or those with certain Creative Commons licenses, often called Open Educational Resources (OER), are legal to use for educational purposes.

How often do you engage in these practices related to open educational resources (OER)?

	Never	Rarely	Sometimes	Often	A great deal
Search for OER on the open Web	○	○	○	○	○
Download OER	○	○	○	○	○
Change OER to suit your needs	○	○	○	○	○
Remix different OER	○	○	○	○	○
Share OER that you change or remix	○	○	○	○	○

Teachers often create, license and share their own educational resources on the open Web. Please indicate how often you engage in these practices.

	Never	Rarely	Sometimes	Often	A great deal
Create your own					

educational resources	○	○	○	○	○
Add Creative Commons licenses to the educational resources you create	○	○	○	○	○
Share on the open Web the educational resources you create	○	○	○	○	○

How do you share your knowledge of learning and teaching on the open web? Please select all responses that apply.

- ○ Post on Facebook
- ○ Upload resources I create to a Wiki
- ○ Write a reflective blog post
- ○ Participate in a video conference
- ○ Participate in online courses
- ○ Send out links via Twitter
- ○ Upload images to share on Flickr
- ○ Participate in a Tweet Chat
- ○ Collaborate using Google Docs
- ○ Create videos and share via YouTube
- ○ Other (please elaborate)

Why do you share your knowledge of learning and teaching on open Web? Please select all responses that apply.

- ○ To seek feedback
- ○ To make my work visible
- ○ To develop my online reputation
- ○ To be transparent about what I'm doing
- ○ To engage a new audience
- ○ To help other teachers
- ○ Other reasons (please elaborate)

To what extent do you agree or disagree with the following statements about the impact professional learning on the open Web has on you.

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
My digital literacy skills are developing	○	○	○	○	○
I reflect more on my teaching practice	○	○	○	○	○
My thinking is challenged	○	○	○	○	○
Unexpected learning occurs	○	○	○	○	○
I am more exposed to cultural diversity	○	○	○	○	○
It broadens my knowledge about STEM education	○	○	○	○	○
I feel less isolated	○	○	○	○	○
It encourages me to be creative	○	○	○	○	○
It gives me confidence to teach beyond my areas of expertise	○	○	○	○	○

Please describe other impacts your professional learning on the open Web has on you and your teaching practice.

Part B: Demographic Information

The following questions are designed to gather some basic information about you and your teaching position.

In which year level/s are you currently teaching? Please select all that apply.

- ☐ Foundation (prep)
- ☐ Level 1
- ☐ Level 2
- ☐ Level 3
- ☐ Level 4
- ☐ Level 5
- ☐ Level 6
- ☐ Level 7
- ☐ Level 8
- ☐ Level 9
- ☐ Level 10
- ☐ Level 11
- ☐ Level 12

What is your gender?

- ○ Male
- ○ Female
- ○ Other

What is your age?

- ○ 20 - 29 years
- ○ 30 - 39 years
- ○ 40 - 49 years
- ○ 50 - 59 years
- ○ 60 + years

Where do you live?

- ○ Victoria
- ○ New South Wales
- ○ Western Australia
- ○ Queensland

- Tasmania
- Northern Territory
- South Australia
- Australian Capital Territory

How many years of teaching experience do you have?

- 1 to 3
- 4 to 6
- 7 to 18
- 19 to 30
- 31 to 39
- 40+

In which learning areas do you teach? Please select all that apply.

- Information and Communication Technology (ICT)
- Science
- Biology
- Chemistry
- Physics
- Mathematics
- Geography
- Design and Technologies
- Digital Technologies
- Environmental Science
- Health and Physical Education
- Other (please list)

On what basis are you currently employed?

- Casual relief teacher
- Contract teacher
- Permanent part-time teacher
- Permanent full-time teacher
- Other (please specify)

Where is the school you are currently working in located?

- ○ Capital city
- ○ Metropolitan area
- ○ Regional city
- ○ Rural or remote area

End of Survey Part A and B

As part of this study a group of teachers will be invited to participate in Phase 2, which includes an interview and participant observations. By completing the expression of interest form below, you are indicating interest and willingness to be considered for Phase 2.

Would you be interested in participating further in this study?

- ○ Yes
- ○ No

If you answered yes to the previous question, please enter your email address.

Thank you for completing this survey, I remind you that selecting the submit button below is an indication of your consent to participate in the survey. You will be notified shortly regarding your participation in Phase 2.

Appendix 3. First Email to Participating Teachers

Dear Participant,

Thank you for deciding to respond to the expression of interest form for this study. I ask for your participation in completing a survey, which can be found here: https://usqadfi.au1.qualtrics.com/SE/?SID=SV_1HzSmDYe1rUPjhP

The survey is part of my PhD study conducted through the University of Southern Queensland. The purpose of this study is to investigate the practices and learning experiences of teachers who use social media, web tools and open educational resources to self-direct their professional learning on the open Web.

Information about the survey

Your participation in the survey is entirely voluntary, there is no obligation and you are free to withdraw at any time. Further details can be found on the Participant Information Sheet, attached to this email.

The survey has 26 questions and will take approximately 15 to 20 minutes to complete.

The project has approval from USQ's Human Research Ethics Committee (Approval number H15REA257).

Please send me an email if you wish to receive a summary of the results or if you have any questions about this research.

Many thanks for your interest and support.

Kind regards,

Penny Bentley

PhD candidate

University of Southern Queensland

Web: http://www.usq.edu.au/contact

Appendix 4. Survey Participant Information Sheet

University of Southern Queensland

Participant Information for

USQ Research Project

Survey

Project Details

Title of Project:	Open Educational Practices and Australian STEM Teachers' Professional Learning
Human Research Ethics Approval Number:	H15REA257

Research Team Contact Details

Principal Investigator Details

Mrs Penny Bentley
Email: penbentley58@gmail.com
Mobile: 0448 665 429

Supervisor Details

Associate Professor Shirley Reushle
Email: shirley.reushle@usq.edu.au
Telephone: 0746312292

Description

This research is being undertaken as part of a PhD study.

The purpose of this project is to investigate the role of open educational practices in the professional learning of Australian science, technology and mathematics teachers. Of interest are the practices and learning experiences of teachers who use social media, web tools and open educational resources to self-direct their professional learning on the open Web.

The researcher requests your assistance because you have expressed an interest in participating in the first phase of this project.

Participation

Your participation in an online survey is requested because you kindly responded to the expression of interest form circulated on social media, and you meet the criteria for participating in this study.

The survey will take approximately 15 to 20 minutes of your time.

This survey will ask a series of questions to explore your open educational practices, such as:

1. How do you use social media for professional learning?
2. What professional learning do you gain from your experiences of social media?
3. Why do you use social media for professional learning?

Your participation in this project is entirely voluntary. If you do not wish to take part, you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. You may also request that any data collected about you be destroyed. If you do wish to withdraw from this project or withdraw data collected about you, please contact the researcher (contact details at the top of this form).

Expected Benefits

It is expected that this project will directly benefit you by delivering an improved understanding of open educational practices and their role in providing effective professional learning experiences for Australian science, technology and mathematics teachers.

Risks

There are no anticipated risks beyond normal day-to-day living associated with your participation in this project.

Privacy and Confidentiality

All comments and responses will be treated confidentially unless required by law.

Any data collected as a part of this project will be stored securely as per University of Southern Queensland's Research Data Management policy. The only people who will have access to the research data will be the USQ researchers directly involved in the project.

Data collected during the study may be used to inform future research. Information gained during the study may be published, however data will not be identified and any personal information will remain confidential.

Consent to Participate

Clicking on the 'Submit' button at the completion of the online survey is accepted as an indication of your consent to participate in this project.

Questions or Further Information about the Project

Please refer to the researchers' details at the top of the form to have any questions answered or to request further information about this project.

Concerns or Complaints Regarding the Conduct of the Project

If you have any concerns or complaints about the ethical conduct of the project you may contact the University of Southern Queensland Ethics Coordinator on (07) 4631 2690 or email ethics@usq.edu.au. The Ethics Coordinator is not connected with the research project and can facilitate a resolution to your concern in an unbiased manner.

Thank you for taking the time to help with this research project.
Please keep this sheet for your information.

Appendix 5. Pilot Interview Teacher Feedback

	Feedback from Teacher 1
Researcher	This concludes the pilot interview, do you mind if I ask you for some feedback about the questions, or your experience of being interviewed? Do you sort of understand what I was getting at?
Teacher 1	Yeah, some of the questions are hard to answer Penny, because they are very open ended. I just feel like I've been rambling on. Sometimes I found it a bit exhausting (pause), it's sort of like asking kids and teaching it and teasing it, then you think "I've said that, I've answered that", but that's the nature of the style of interviewing. There was a point where you said something, where you asked about the open Web, and I guess I'm not really familiar with the term open Web, I told about online. I was trying to think "is that the same thing?" But there was one point where you were talking about the open Web and then you gave me a few concrete suggestions to talk about this or that (pause) and that gave me something to hang my words on. It just helped me, like I needed more direction. And that wasn't you putting words in my mouth, it was just "what are you talking about, what do you actually want to know?" Are you able to use concrete analogies? Or, being able to have a few short, sharp questions that will elicit obvious answers…you don't necessarily need to know what the answers are, but I think the open-ended questioning can be a bit exhausting and you don't feel as though you're going anywhere.
	Feedback from Teacher 2
Researcher	Can you just give me a little bit of feedback on the questioning? Did you understand what I was getting at, did you find the questions too abstract?
Teacher 2	Look, you've got a really tough interviewee cos I go off on tangents. I answer questions by telling a story. So, I hope to goodness I gave you answers that you needed.
Researcher	Through the probing and the questions I asked you…it's open ended, so I let you go on a journey but through that journey you actually answered those questions in a slightly different order. When I come to analyse the interview I suspect that it will all fall out, the information, anyway. I interviewed someone yesterday and I didn't put it in the context of an example and she found it a bit awkward not being able to relate back to a real experience of hers. I wanted to try that, and it seemed to work OK.
Teacher 2	When you asked me for an example of an effective professional learning, online situation, I got stuck trying to find an example that I thought would be valuable to analyse, to tease out that information. So I was a bit lucky, I don't know whether you could see it but I was certainly hunting around for something viable and valuable to do. It worked, your questions make sense, they didn't seem to have any particular sort of pathway…you know, at the beginning, the middle and towards the end.
Researcher	That's interesting that you say that when I'm asking you to find an example of professional learning, it's exactly what happened with the last teacher. I'm finding the open Web is not really made up of events, that a lot of the best learning is serendipitous, that you don't know it's coming and it happens just because you're there. So that's an interesting insight from two of you.
Teacher 2	Probably the best way to suggest would be if you can find some people who blog, because they capture their memories a bit better. My situations come and go, if I blogged then I'd be able to look back and go "oh, that was a good opportunity". But you're right, it's all serendipitous, and it's exciting because it's serendipitous, but I think the negative of it is you can jump to the next thing and the next thing and the next thing before you've actually applied it, learnt it, cemented it and developed it, I think.

Appendix 6. Final Interview Guide

Experience of Professional Learning through Open Educational Practice
A Phenomenographic Study of Australian STEM Teachers
Interview Guide

Thank you for completing the online survey and agreeing to be interviewed. The **survey** gave me some insight into the practices of teachers using the open Web for professional learning and the purpose of this interview is to hear about your experiences in more detail. There's no right or wrong answer to the questions. This interview will take approximately 60 minutes and will be audio recorded. You are welcome to a copy of the transcript. Your confidentiality and privacy is respected so you will not be identifiable in any publications arising from this work. You can withdraw at any time.

Contextualising Statement…are we on the same page? (as opposed to checking with participants after data analysis)

Before we start, it's important we both have the same understanding of what professional learning on the open Web means. Let's discuss a few terms so we are on the same page. I'll be focusing on your experience of professional learning on the open Web, in the context of STEM education. Professional Learning is anything you believe you have learned that is relevant to you. STEM Education covers the disciplines of science, technology, engineering and mathematics. The open Web: platform you access via the internet, unrestricted access, free resources and web tools, culture of participation and sharing. By experience I mean your approach to professional learning and what you learn from your experience.

Concrete Example

I'd like you to describe a recent experience you've had of professional learning on the open Web.

1. **How** did you use the open Web for this professional learning experience? What was your approach, your actions, what did you do (your methods, techniques, procedures, practices, way of doing things)
2. What did you learn (learning did you gain) from your professional learning experience on the open Web? (Conception)
3. Why did you approach your professional learning this way? (Intention)
4. What impact did this learning have on you as a teacher?
5. What, if any, difficulties, problems, setbacks have you faced during this experience?
6. Before we conclude, is there anything else you would like to add?

Prompts

- Please explain that further, please elaborate, tell me more
- What do you mean by that
- Please explain that in a different way
- Please give me an example
- Why did you do it that way? What were you hoping to achieve?
- Why was that important to you?

Appendix 7. Second Email to Participating Teachers

Dear Teacher,

Thank you for completing my survey earlier this term and expressing an interest to participate in Phase 2 of this study, the interview. I am writing to seek your consent for participation in Phase 2 and to arrange an interview sometime, at your convenience, over the next 2 weeks.

- could you please email me at penbentley58@gmail.com with a suitable day and time for an interview. Are you able to connect via Skype?
- Please use this link to complete the online consent form: https://usqadfi.au1.qualtrics.com/jfe/form/SV_9XOOfrOfeqBcOZD

The interview is part of my PhD study conducted through the University of Southern Queensland. The purpose of this study is to investigate the experiences of Australian science, technology and mathematics teachers using the open Web for professional learning. Of interest are the practices and learning experiences of teachers who use social media, web tools and open educational resources to self-direct their professional learning on the open Web.

Information about Phase 2: Interview

Your participation in Phase 2 is entirely voluntary, there is no obligation and you are free to withdraw at any time. Further details can be found on the Participant Information Sheet, attached to this email.

The interview will take approximately 60 minutes. The project has approval from USQ's Human Research Ethics Committee (Approval number H15REA257). Please send me an email if you wish to receive a transcript of the interview or if you have any questions about this research.

Many thanks for your interest and support.

Kind regards,

Penny Bentley

PhD candidate

University of Southern Queensland

Web: http://www.usq.edu.au/contact

Appendix 8. Interview Participant Information Sheet

University of Southern Queensland

Participant Information Sheet

USQ Research Project

Interview

Project Details

Title of Project:	Open Educational Practices and Australian STEM Teachers' Professional Learning
Human Research Ethics Approval Number:	H15REA257

Research Team Contact Details

Principal Investigator Details

Mrs Penny Bentley
Email: penbentley58@gmail.com
Mobile: 0448 665 429

Supervisor Details

Associate Professor Shirley Reushle
Email: shirley.reushle@usq.edu.au
Telephone: 0746312292

Description

This research is being undertaken as part of a PhD study.

The purpose of this project is to investigate the role of open educational practices in the professional learning of Australian science, technology and mathematics teachers. Of interest are the practices and learning experiences of teachers who use social media, web tools and open educational resources to self-direct their professional learning on the open Web.

The researcher requests your assistance because you have expressed an interest in participating in the second phase of this project.

Participation

Your participation will involve an interview that will take approximately 60 minutes of your time.

The interview will take place online (using Skype or Google Hangouts) at a time that is convenient to you.

Questions will include:

- What do you consider to be effective professional learning?
- Please describe how you use Twitter for effective professional learning.

The interview will be audio recorded.

Your participation in this project is entirely voluntary. If you do not wish to take part you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the

project at any stage. If you do wish to withdraw from this project or withdraw data collected about you, please contact the Research Team (contact details at the top of this form).

Your decision whether you take part, do not take part, or to take part and then withdraw, will in no way impact your current or future relationship with the University of Southern Queensland.

Expected Benefits

It is expected that this project will directly benefit you by delivering an improved understanding of open educational practices and their role in providing effective professional learning experiences for Australian science, technology and mathematics teachers.

Risks

There are no anticipated risks beyond normal day-to-day living associated with your participation in this project.

Privacy and Confidentiality

All comments will be treated confidentially unless required by law.

You will have the opportunity to verify your comments prior to final inclusion into the study. The researcher will be the only person having access to the recording during the transcription process.

Data collected during the study may be used to inform future research. Information gained during the study may be published, however data will not be identified and any personal information will remain confidential.

Any data collected, as a part of this project, will be stored securely as per University of Southern Queensland's Research Data Management policy.

Consent to Participate

Please complete an online consent form to confirm your agreement to participate in this project via the link provided in the email to which this participant information sheet is attached, prior to participating in your interview.

Questions or Further Information about the Project

Please refer to the Research Team Contact Details at the top of the form to have any questions answered or to request further information about this project.

Concerns or Complaints Regarding the Conduct of the Project

If you have any concerns or complaints about the ethical conduct of the project you may contact the University of Southern Queensland Ethics Coordinator on (07) 4631 2690 or email ethics@usq.edu.au. The Ethics Coordinator is not connected with the research project and can facilitate a resolution to your concern in an unbiased manner.

Thank you for taking the time to help with this research project.
Please keep this sheet for your information.