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# Repositioning teachers and learners in senior science for 21st century learning

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# Abstract

This thesis explores how the turn towards '21st century learning' might influence senior secondary science education in the context of high stakes summative assessment in Aotearoa New Zealand. Significant in the set of assumptions and ideals associated with 21st century learning is the expectation that learning is more personalised to address and allow for diverse student needs and interests. However, in the reality of classroom life, a question remains as to if and how 21st century ideals might translate into practice.

A social constructionist theoretical orientation directed attention to the way 21st century learning as a discourse constructs certain conditions of possibility for teaching and learning. In turn, these conditions were viewed as shaping different possibilities for teacher and student positions and identities.

Four macro-level elements of curriculum, assessment, physical spaces, and digital technologies were used to frame an examination of the ways in which the discourse of 21st century learning might play out in senior secondary science. Interpretations of science as a key learning area in the New Zealand curriculum (NZC) and the National Certificate of Educational Achievement (NCEA) as the New Zealand secondary school exit qualification provided the contexts for elements of curriculum and assessment. Research was conducted in schools designed as open, shared, flexible learning spaces (FLS), incorporating wired and wireless technologies. This provided the context for the elements of physical space and digital technologies.

The research was designed in two phases. In phase one, three case studies were undertaken to ask: What *does* senior secondary science learning look like in FLS schools when teachers and students are focussed on NCEA assessment? In phase two, three cycles of collaborative action research were undertaken over eight months with one teacher and her year 12 science class to explore: What *could* senior science learning look like? Qualitative data generated from interview and participant observation in both phases was analysed using thematic analysis to understand what science learning looked like or could look like. Social constructionist ideas of discourse, positioning, and identity were used to theorise and explore the overarching research question of how the discourse of 21st century learning might influence notions of senior secondary science to reposition teachers and learners of science.

Findings show how the multifaceted identities taken up by teachers and students were shaped by the pedagogical possibilities created and available within the dynamic interplay between the four elements. Teachers and students could be seen to be positioned by and to position themselves within discourses of 21$^{st}$ century learning as personalisation and choice, and traditional science schooling, in action and tension. Some aspects of NCEA assessment acted to strengthen the traditional science schooling discourse which foregrounds science as knowledge-based and supports identities of teacher-expert as transmitters of knowledge. Other aspects of NCEA provided openings in line with science as inquiry as advocated in the NZC. Some aspects of FLS environments did not support some teachers' view of traditionally effective approaches to science teaching and practical work. However, the affordances of digital technologies and the fluidity and social flow of flexible spaces enhanced possibilities for many forms of learning choices. Flexible spaces supported team teaching of larger groups and collaboration of teachers across science disciplines.

Teachers responded to these openings by scaffolding different types of learning choices for diverse senior students in what, why, where, how, and with whom to learn, at different levels of openness in science inquiry. However, some students did not take up the full scope of the opportunities offered, especially where these were in tension with students' ideas of how best to be successful in terms of achieving credits in NCEA. Findings reinforce the importance of the teacher's role in scaffolding student autonomy to make choices and to achieve in student-directed inquiries. Overall, and in spite of the challenges and tensions that teachers and students faced, this research identifies opportunities for broadening the definition of 'good' science teacher and learner to include the offering and uptake of a range of learning choices in senior science inquiry as part of high stakes assessment.

This research contributes insights in the form of situated stories of the struggles and achievements of teachers and students: what *was* happening and what *did* happen as they were positioned and as they acted to reposition themselves to take on different science teacher and learner identities in contexts of high stakes NCEA assessment in 21st century FLS environments. A range of implications for learning space design, curriculum and assessment policy, and directions for further research into science inquiry and digital pedagogies are outlined.

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## 1.1 Introduction to 21st century learning

This thesis explores the turn towards '21st century learning' and examines ways in which this might influence notions of senior secondary science in high stakes assessment environments to reposition teachers and students of science in Aotearoa New Zealand.

Twenty-first century learning is often linked with future-focussed education agendas for economic, environmental, social, and personal development (Aspin, Chapman, Evans, & Bagnall, 2012; Organisation for Economic Co-operation and Development [OECD], 2018). It is a frequently referred to but often uncritically examined concept nationally and internationally in the fields of curriculum and assessment reform (e.g. Gilbert, 2015; Griffin & Care, 2015; Griffin, Care, & McGaw, 2012; Ministry of Education, 2007a; Saavedra & Opfer, 2012). It is also prominent in learning environment policy and research (e.g. Campbell, Saltmarsh, Chapman, & Drew, 2013; Li, Locke, Nair, & Bunting, 2005; OECD, 2006), and research on the development of digital literacies and pedagogies (e.g. Erstad, Voogt, Mishra, & Dede, 2013; Kereluik, Mishra, Fahnoe, & Terry, 2013).

Key aspects of 21st century learning include disciplinary knowledge as well as skills, competencies, and dispositions necessary for life and learning, such as collaboration, creative and critical thinking, communication, problem solving, teamwork, self-management, sustainable citizenship, personal and social responsibility, and learning to learn (Griffin et al., 2012; Hipkins, Bolstad, Boyd, & McDowall, 2014; Ministry of Education, 2007a; OECD, 2005, 2011, 2013; Voogt & Roblin, 2012).

It is argued by some that the notion of 21st century learning has grown out of the need for a changing work force skills-base due to the evolution of a 'knowledge age'. In the previous industrial age, economic productivity relied more on natural resources, primary agrarian production and mass production. In the technological, digitised 'knowledge age', knowledge and ideas drive economic productivity. Where once knowing and having knowledge was valued in and of itself, learners in the knowledge age need to develop the skills and competencies that enable them to keep on learning and to use disciplinary and inter-disciplinary integrated knowledge to cope with complex problems in new and unknown contexts (Benade, 2015b; Bolstad & Gilbert, 2012; Griffin et al., 2012; Ministry of Education, 2015b; OECD, 2009; Voogt & Roblin, 2012).

Associated with this shift in conceptions and use of knowledge is a rejection of 'one-size-fits-all' approaches to education. Twenty-first century learning is further characterised by a move towards student-centred models which recognise individual differences in prior knowledge, abilities, learning styles, interests, and motivation, as well as in socio-economic and socio-cultural status (Dumont, Istance, & Benavides, 2010). Although the idea of acknowledging learners as socially and culturally located and diverse is not new (Voogt & Roblin, 2012), perhaps most significant in the turn to 21st century learning is the idea that learning should be personalised and self-regulated for each learner, not just at the shallow level of "mass customisation" but "deeply" (Leadbeater, 2006, p. 112) or "profoundly" personalised (Dumont et al., 2010, p. 18). Leadbeater (2006) posits that in deeply personalised approaches, curriculum is not driven by a predetermined set of content but by students' needs and interests as they shape their own learning at an individual level.

The sum of these ideas represents an educational agenda which signals a shift away from traditional pedagogical practices such as the transmission of knowledge, the general consensus being that the adoption of competency-based, personalised principles of 21st century learning is essential to equip young people to live well in a changeable, technology-rich society (Benade, 2015a, 2015b; Dumont et al., 2010; Facer, 2012; Gilbert, 2005).

## 1.2 Twenty-first century learning as a discourse

In this study, I recognise 21st century learning as a discourse (Burr, 2003; Foucault, 1972). I use a social constructionist interpretation which conceives of discourses as specific clusters of language, social practices, or knowledge that together produce, construct, or represent objects or events in certain ways (Burr, 2015, p. 76). The event or object under study in this research is defined as 'senior secondary science teaching and learning in Aotearoa New Zealand'. I focus on how teachers and students of senior science are positioned in certain ways within the discourse of 21st century learning, which I interpret as a collection of institutional structures and meanings which construct certain pedagogical possibilities and offer certain ways of being teachers and students while excluding others (Graham, 2011).

The discourse of 21st century learning is pervasive within and across many aspects and sectors of education both internationally (e.g. Facer, 2011; Fullan, Quinn, & McEachen, 2018; OECD, 2009, 2011, 2013, 2018; Prensky, 2013) and nationally (e.g. Abbiss, 2013; Benade, 2015a, 2015b; Ministry of Education, n.d.-b; McPhail, 2016). In the paragraphs below, I develop examples of this discourse at work.

Internationally, the notion of 21st century learning is recognisable as a discourse as the idea is taken up by education futurists and commentators to emphasise skills and competencies necessary for a new age of continuous, adaptive learning. Prominent British politician David Miliband as early as 2003 proclaimed in a speech to the annual North of England Education Conference that "one of the core functions of 21st century education is learning to learn in preparation for a lifetime of change". Guy Claxton, a well-known British academic, asserts that "being an effective, powerful, real-life learner is a useful thing to be", and that 21st century education should help young people develop this generic capacity to learn (2007, p. 116). Keri Facer (2011) in her book titled *Learning futures* critically reimagines the future of school-based education in the face of social and technological change. She presents strategies for educating "new millennials" or "digital natives" (p. 18) as lifelong learners building sustainable, equitable futures (p. 133). These ideas constitute a discourse of 21st century learning in that they foreground issues of continuous learning and future-focussed, technology-based education. Marc Prensky (2013) maintains that in the 21st century, technology is the key to "thinking about and knowing about the world" (p. 23) and because of this, a radical re-thinking of school curricula is required. Prensky calls for the elimination of "bloated and outdated" single subject curricula, claiming schools should focus instead on skills such as critical and creative thinking, self-management, and persistence as students pursue learning that is project-based, real-world oriented, and different for every student (p. 26). In another example, Fullan et al. (2018) in their recent book *Deep learning: Engage the world, change the world*, argue that student-owned, personalised learning in the form of inquiry or project-based approaches increases student engagement and builds skills, knowledge, self-confidence, and self-efficacy (p. 9).

Twenty-first century learning as a discourse is recognisable in publications by global organisations that drive social, economic, and environmental change. For example, the OECD has been influential over time in drawing together policy and research from member countries in the push towards designing learning environments for the 21st century (OECD, 2009, 2011, 2013, 2018), in defining the nature of 21st century skills and competencies (Dumont et al., 2010; OECD, 2005), and in exploring ways in which technologies can be used to shape 21st century education (OECD, 2011). The OECD's assertion that "the term 'school' no longer captures the rich purpose and function of new learning environments" (OECD, 2006, p. 3) has instead seen the introduction of the phrase "innovative learning environment" (ILE) (OECD, 2013, p. 11). This represents a complete 21st century education ecosystem including educators, learners, policies, resources, and social interactions. The use of the word 'innovative' is significant, carrying connotations of doing things differently; of re-imagining and re-structuring teaching and learning for a new age. As notions of teaching and learning evolve, so have physical learning environments (OECD, 2011). Whereas ILE is used in association with the OECD's conception of a complete 21st century education ecosystem, the term "flexible learning space" (FLS) is used to signify the design and resourcing of a new kind of open, flexible, classroom space (OECD, 2013, p. 60).

In another example, a large-scale, multi-year, multi-national (Australia, Finland, Singapore, the United States, Costa Rica, and the Netherlands), technology industry (Cisco, Intel, and Microsoft) - university partnership, led by researchers at the University of Melbourne, resulted in a research and development project: Assessment and Teaching of 21st Century Skills (ATC21S). The project focussed on defining 21st century skills and finding ways to measure these. Statements of purpose included a challenge to transform education for the 21st century because "today's curricula do not fully prepare students to live and work in an information-age society" (ATC21S, 2012, para. 1). Twenty-first century skills were defined in four broad categories: ways of thinking, ways of working, tools for working, and ways of living in the world. Major project outcomes included the development of conceptual frameworks and exemplar tasks for the 21st century skills of collaborative problem solving and ICT literacy, and development of mechanisms for digital assessment of these skills (Griffin & Care, 2015).

Twenty-first century learning has been recognised as a discourse in the New Zealand research space (Abbiss, 2013; Benade, 2015a, 2015b; McPhail, 2016). Abbiss (2013) explores the idea of discourses relating to 21st century education for the social sciences, asserting that "New Zealand government education policy is producing and sustaining regimes of truth that are increasingly focussed on the construction and transformation of education under future-focussed, 21st century frames" (p. 9). Abbiss argues that the 21st century education discourse presents both challenges and transformative opportunities for social science educators when examining the alignment of specific skills and disciplinary knowledges associated with the social science curricula and the more generic 21st century skills and knowledge frames. In contrast, Benade (2015a) presents a critical argument challenging the discourse of 21st century learning. Benade epitomises the 21st century learning discourse as a focus on skills and competencies, the use of technological tools, and a fixation on personalised learning. According to Benade, the discourse dismisses current education structures as failing to prepare students for an unpredictable, rapidly changing future. He cautions that wholesale alignment with this 21st century discourse might be associated with moral costs, for example, the "obscurity and anonymity" of online spaces may have negative social or relational effects (p. 946). McPhail (2016) argues that many ideas from the discourse of 21st century learning have been making positive changes in music education. These changes have included student ownership of curriculum, group learning and assessment, a focus on popular music rather than classical traditions, and an emphasis on processes of composition or music-making rather than knowledge of facts and of traditional, canonical, works. He argues, on the other hand, that there have been unintended, less positive consequences. These include the tension between allowing student choice in curriculum content and the necessity of teaching foundational, generative concepts. McPhail concludes that the experiences of music educators may have relevance for educators in other subject areas as they negotiate the shift towards 21st century learning.

When examining New Zealand Ministry of Education policy and resources, it is also possible to recognise the discourse of 21st century learning at work. Examples are found on the Ministry of Education's Te Kete Ipurangi (TKI) website (Ministry of Education, n.d.-b). The Māori word 'kete' means 'basket', and TKI is positioned as an online knowledge basket or education portal for the New Zealand education sector. It curates a wealth of information, resources, and curriculum materials to support teaching and learning. A kete related to leadership and strategic planning curates resources to support the design, development, and transition to flexible learning spaces (FLS) as one component of evolving innovative learning environments (ILE). In the kete related to curriculum, challenges for learning and assessment in the 21st century are said to include managing a shift from traditional pencil and paper assessment to those which use multimodal communication methods to provide a range of evidence across a wide range of learning outcomes. In the kete related to digital learning, it is claimed that digital technologies assist students to take control of their own learning, where learning objectives, content, method, and pace all may vary for each individual learner. Further evidence of the discourse at work is found in this statement about inquiry learning: "An inquiry-based approach is driven by students' curiosity about the world around them. It encourages connection, co-operation, and collaboration by allowing students to pose and solve problems together and with their communities in shared, authentic learning experiences" (para. 1).

In sum, a discourse is a specific collection of language, knowledge and practices that construct or represent objects or events in certain ways. The discourse of 21st century learning involves knowledge use rather than just knowledge acquisition, and sets up expectations for skills-based, competency-based, personalised approaches in student-directed, technology-rich learning environments. In 21st century learning, students make learning choices and education is meaningful, relevant, and effective for each individual.

## 1.3 A framework for a 21st century learning environment

As the discourse of 21st century learning is the umbrella theme in this thesis, and as learning environments are complex and multidimensional, an exploration of the ways that the discourse might play out in New Zealand secondary schooling requires a framework within which to understand and meaningfully examine it. The curriculum - evaluation/assessment - pedagogy triad is a well-established structure through which ideas about teaching and learning are constructed and communicated (Corrigan, Gunstone, & Jones, 2013; Hayward, Higgins, Livingston, & Wyse, 2016; Pendergast, Bahr, & Hunter, 2010; Penney, Brooker, Hay, & Gillespie, 2009). In this thesis, I argue and provide evidence that curriculum and assessment policies are two elements of the discursive environment that frame possibilities for pedagogical action. Because of the international and national political focus within the 21st century learning discourse on the integration of digital technologies (Erstad et al., 2013; Kereluik et al., 2013), I include this as an element that impacts on possibilities for pedagogy. Lastly, because of the national and international political and policy focus on redesigned learning spaces, I also include this element as part of the framework I use to examine the possibilities for 21st century learning in senior secondary science.

In this research, I therefore recognise four separate yet interconnected elements of a learning environment: physical space, digital technologies, curriculum, and assessment. The ways in which these four elements are reflected in current policy and research will be further examined in chapter three. The next section provides a justification and brief overview of each of these elements.

**Physical space**

Flexible learning spaces (FLS) are designed to facilitate student-centred, rather than teacher-led approaches (Dovey & Fisher, 2014; Wright, 2017). Physical attributes include open spaces which can accommodate larger groups of students and teachers, rather than cellular spaces where a single teacher takes charge of a single class (Dovey & Fisher, 2014). Supporting a departure from teacher-led learning, there is often no focal point or 'front of the room' (Alsaif, 2014; Benade, 2015a; Bisset, 2014; Osborne, 2013). Instead, "agile" features (Dovey & Fisher, 2014, p. 58) such as moveable fittings, furniture, and sliding walls (Ministry of Education, 2016a, 2016b; Wright, 2017) allow for different work configurations that cater for team teaching and group or individual learning. Flexible learning spaces are designed to have good acoustics and optimal ventilation, temperature, and lighting (Fisher, 2002; Ministry of Education, 2017a; Sheerin, 2008). Flexible learning spaces also incorporate wired and wireless technologies that support digital pedagogies and enable students to access digital devices when and as they require them (Dovey & Fisher, 2014; Osborne, 2013).

**Digital technologies**

Twenty-first century learning environments are technology-rich (Benade, 2017a; Ministry of Education, 2015c). Teachers and students have ready access to networked digital devices and virtual learning spaces that allow for new ways of storing, accessing, developing, and using knowledge (Csapó & Funke, 2017). These digital technologies allow students to connect globally and locally to information and learning communities outside of school, and to continue with their learning anywhere, at any time (Fletcher, Tobias, & Wisher, 2007; OECD, 2013; Prensky, 2012). They also enhance students' abilities to personalise their learning programmes.

**Curriculum**

The eight well-known frameworks for 21st century competencies that Voogt and Roblin (2012) identified as informing curriculum development internationally converge on a common set of competencies: collaboration, communication, ICT literacy, and social and/or cultural competencies (including citizenship). Most of these frameworks also mentioned creativity, critical thinking, productivity, and problem-solving (p. 315). Connected with ideas of 'knowledge-in-use' rather than knowledge as static and remembered; personalised, project-based or inquiry learning, and cross-curricular or multi-disciplinary investigations are emphasised in 21st century curricula internationally (Darling-Hammond, 2012; OECD, 2005, 2006; Wiliam, 2010) and in New Zealand (Ministry of Education, 2007a).

**Assessment**

Current views of assessment encompass a variety of models that aim to assess more than just knowledge reproduction (Fensham & Rennie, 2013; Griffin & Care, 2015). Formative assessment in the form of regular and meaningful feedback is acknowledged as a central feature and powerful support for 21st century learning (Wiliam, 2010), and a key purpose for assessment in New Zealand (Absolum, Flockton, Hattie, Hipkins & Reid, 2009; Ministry of Education, 2007a, 2011).

Methods and models of within-school, task-based or skill-based performance assessments are also associated with 21st century learning, with these positioned as appropriate for evidencing learning that has developed within project-based or inquiry-oriented learning (Darling-Hammond, 2012; Darling-Hammond & Adamson, 2014; Griffin et al., 2012). In New Zealand, the National Certificate of Educational Achievement (NCEA) is a flexible, modular, standards-based system including internal (in-school, teacher-based) and external (examination-based) assessment (New Zealand Qualifications Authority [NZQA], n.d.-a)[1]. As such, the NCEA offers teachers the ability to assess a range of learning outcomes using a variety of tasks and contexts.

To recap, in this thesis the discourse of 21st century learning is understood as being framed by a collection of institutional structures and policies associated with elements of redesigned physical spaces, technological evolution to digitised learning, and curriculum and assessment reform. The ideas and affordances within these four elements and the framework they provide influence possibilities for what teachers and students can do or aspire to do in practice.

## 1.4 Changing identities for teachers and students

In shaping institutional structures and policies, the discourse of 21st century learning contemporaneously shapes the *conditions of possibility* for teacher and student actions and interactions (Melville & Bartley, 2013; Zembylas, 2003 after Foucault, 1979). In other words, it may be more possible to be *one* type of teacher or student than another, *different* type of teacher or student. Certain teacher and student identities become more and less available to take up, meaning "discourses produce subjects as well as objects" (Graham, 2011, p. 671). For example, a move from teacher-led to student-centred approaches disrupts established conceptions of teachers as experts who possess disciplinary knowledge which they impart to students. In personalised, student-directed learning, rather than teachers being a "sage on the stage", they become a "guide on the side" (Wiliam, 2010, p. 152).

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[1] Senior secondary learning (years 11 to 13, curriculum levels six to eight) is assessed at levels one to three of the National Qualifications Framework (NQF) by NCEA, which is administered by the NZQA (New Zealand Qualifications Authority). In completing an NCEA qualification, students gain credits towards a certain certificate level by completing separate but discipline-related achievement standards.

Where students were consumers of content, the focus in a 21st century frame is on students as independent learners and producers of knowledge (OECD, 2006).

To problematise the idea that the discourse of 21st century learning necessarily translates to a different reality in terms of teacher and student identities at the coalface of classroom life, and to further set the scene for the research, I now establish the ancestry of this study as it emerged from my professional experiences as an educator.

## 1.5 My personal back story

At the time of beginning this study I was a secondary teacher educator, an ex-secondary science teacher and parent of secondary school-aged children. My interest in this research stemmed from two aspects of my professional life.

One aspect which ignited my interest, were visits as part of my teacher educator role to a small number of new schools working in re-designed or newly built FLS. Each FLS school seemed to be slightly different in design, but common elements included large open spaces where two or more classes and teachers worked together and mobile furniture which could be reconfigured as needed. I started imagining what education could be in these spaces.

As I engaged teachers from these schools in conversation, I noticed the explosion of new terms that they were using to talk about teaching and learning. Teachers in FLS schools discussed “breakout spaces”, “frontloading”, “learning commons”, and “workshopping”. I was sensitised to this use of language as I was working with the social constructionist theoretical frame to complete my Master of Education dissertation. A key tenet of social constructionism is that language constructs the social world and structures our experiences (Burr, 2003, 2015). I wondered: Is this new language part of a reconstruction of education, part of a process of being and becoming different types of teachers and students? It seemed to me that conceptual tools of social constructionist theory, for example, constructionist ideas about language, discourse, and identity, might offer a different perspective on the construction of teaching and learning in 21st century contexts and offer useful insights into the process of educational change in New Zealand secondary schools.

Within a constructionist frame, I perceived the "unbundled" (Bolstad & Gilbert, 2012, p. 2) open spaces of FLS to be a physical outworking of the discourse of 21st century learning. I understood the spaces as a new physical reality to which teachers and students must respond, where the unchallenged assumption was that the pedagogical possibilities permitted by these new spaces would (quite literally) furnish the way to a 21st century learning revolution. Yet I knew that open learning space schools had existed before in the 1970s and 1980s and that the initiative had not endured (Cuban, 2004; Dovey & Fisher, 2014; Historic Films Stock Footage Archive, 2013; Horwitz, 1979; Saltmarsh, Chapman, Campbell, & Drew, 2015). What was different this time? I admit to being more than a little cynical of the speed at which new education initiatives can be pushed through at the policy level, leaving teachers to deal with the 'fraught-ness' and 'ought-ness' of making the shift. In spite of this, I was drawn to the idea that more personalised pathways for learning may be possible in these spaces.

The second aspect which influenced my thinking was an early reading of a report to the New Zealand Ministry of Education by Bolstad and Gilbert (2012) titled *Supporting future-oriented teaching and learning: A New Zealand perspective*. In their report, Bolstad and Gilbert (2012) draw together findings from futures-thinking research to suggest principles for a "21st century New Zealand education system" that will prepare young people for a complex and unpredictable future (p. 3). Their vision is premised on the notion that current educational institutions, policies, and practices are not adequate for developing skills and competencies needed to live in a digitally connected, information-saturated world. They argue that ideas about 21st century education have emerged as a result of significant and ongoing social, technological, and environmental change as part of a shift from the industrial age to the knowledge age.

Bolstad and Gilbert assert that New Zealand's education system must be "rebuilt" for the 21st century (p. 65). They cite key principles of personalised, strengths-based and lifelong learning, new ways of thinking about equity and diversity, and a continuous learning interface between school and the wider community as central to this rebuild. In their view, the roles of teachers and students in 21st century learning environments require re-thinking as "we loosen our grip on traditional ideas" (p. 9) about education. School communities must "re-write the script" (2012, p. 4 after Leadbeater, 2006, p. 110) and envision different ways for teachers and students to work together to create or apply knowledge rather than merely reproduce it.

In their report Bolstad and Gilbert issue a challenge - of taking personalised learning further than the shallow level of mass customisation (see also Leadbeater, 2006) already achieved by redeploying existing resources of teachers, time, and space. According to Bolstad and Gilbert, "equity" in education is no longer equated with "sameness" (p. 18). They offer a metaphor for "deeply" personalised learning in senior secondary school of a networked campground, where students plan their path with a teacher/mentor at a central stop before setting off on different "loop tracks" according to their individual aims, strengths, or interests (p. 18). Akin to Leadbeater's (2006) depiction of bespoke learning or "mass personalisation" (p. 106), while there still might be a common core, it is possible to reach different learning destinations via a variety of routes at a speed that suits each diverse individual.

I was attracted to this future-focussed, possibility-thinking about new ways of teaching and learning. I saw the Bolstad and Gilbert report as a synthesis which scrupulously encapsulated the ideals which are foregrounded within a discourse of 21st century learning. The report projected innovative possibilities for a future-oriented New Zealand education system and signalled that in contemporary New Zealand classrooms, acceptable ways of 'doing' school need to evolve. At the same time, my own experiences of education told me that reality did not yet match this rhetoric.

In my experience, senior assessment contexts were one example where reality pushed back against the ideal. The secondary teachers I talked to and observed seemed predominantly focussed on getting their students through NCEA assessment standards. Ideas to do with 21st century competencies and personalised, student-directed learning appeared to me to be disconnected from teachers' relentlessly important task of providing students with the skills and information needed to achieve. Bolstad and Gilbert connect only briefly with the intricacies and demands of senior school assessment, stating in their report that there seems to be variance in teachers' views as to whether current assessment systems do or do not present barriers to curriculum innovation (p. 37). It seemed to me that many teachers and students were continuing to walk the same pragmatic path along the assessment/accountability track, maybe tinkering at the periphery of change, but all the time focussing their real efforts on improving achievement and on helping students gain senior school qualifications.

## 1.6 The research problem

In their report, Bolstad and Gilbert concede that personalised learning is poorly understood, and only implemented in a limited way in a small number of schools (p. 24). They acknowledge that substantial investment in infrastructure and digital resources has not yet revolutionised learning (p. 6). They also note that there is "no model for future practice out there" (p. 48), waiting to be found, and reiterate the call for a significant systems-level change in the way we see curriculum, teaching, and learning, and in the ways teachers and students see themselves.

My own wonderings about these issues included:

- Who are teachers and students in a 21st century transformation of teaching and learning?
- What does personalised learning look like, when superimposed onto high stakes, senior assessment contexts?
- How closely matched are 21st century education writings about who teachers and senior students *could* be, with who they are *able* to be?

Others have pushed back against 21st century learning ideals at the point where these meet the reality of assessment and accountability. For example, Guy Claxton in his discussion of young peoples' desire and capacity to learn, writes:

> Compared to the rhetoric and the good intentions, however, practical progress has so far been disappointing. There is barely a school or a Local Authority in the UK whose Mission Statement does not now include a nod in the direction of preparing their students for 'a lifetime of change' or 'becoming successful learners'. But on the ground, it has proved very hard to prevent these fine words slipping back into a concern with improving test performance (….). Being a 'successful learner' often turns out to mean nothing more interesting than doing well in exams. (2007, p. 116)

In posing the questions above I was cognisant that the constraints imposed by high stakes assessment practices are widely recognised as a barrier to innovation and education reform (OECD, 2013; Wallace & Priestley, 2017). High stakes assessments are named as such because the qualification outcome is important to a range of stakeholders. Black and Wiliam (2007) note that while assessment is concerned with the "*support* of learning", it must also be concerned with "*certification"* purposes (p. 4, emphasis in original). Assessment must answer to both high stakes accountability purposes (Absolum et. al., 2009; Black & Wiliam, 2007; Moeed, 2010) and pragmatic considerations such as ease of use, authenticity, reliability, and moderation processes (Black, 2015; Gillon & Stotter, 2011).

In the context of science education at secondary school level, science is often seen as a knowledge-based subject, with disciplinary content arranged according to layers of conceptual complexity (Bull, Gilbert, Barwick, Hipkins, & Baker, 2010). Jones and Buntting (2013) observe that assessment policies can at once broaden and constrain science pedagogy, citing tensions between 21st century learning goals and what is signalled in assessment policies. Internationally, the demands of assessment have been shown to play a part in maintaining a science status quo (Ajaja, 2012; Carlone, Haun-Frank, & Kimmel, 2010; Danielsson & Warwick, 2014; Tytler, 2010). As Fensham and Rennie (2013) point out, "while innovative science teaching is a familiar idea at the research level, it has not yet been so developed in terms of assessment" (p. 70). Nationally, the NCEA assessment system influences the way science programmes are designed and delivered and can be perceived as a barrier to course and curriculum innovation (Jones & Buntting, 2013). This is in spite of the flexibility that NCEA offers as a modular, internal and externally assessed, standards-based system (Hipkins, 2015; Hipkins, Johnston, & Sheehan, 2016). In a report on a large-scale survey of secondary teachers' perceptions of NCEA undertaken in 2012, Hipkins found in science particularly that teachers' curriculum and assessment thinking were "out of step - with each other and/or with NCEA itself" (2012, p. 81). Science teachers were among those who were more likely to disagree or strongly disagree that NCEA gives them the freedom to design courses or programmes "how we want" (2012, p. 34). More recently, science teachers were still found to be more likely to think that the NCEA science standards do not reflect the 21st century shifts implied by the New Zealand Curriculum (NZC) (Hipkins, 2015; Hipkins et al., 2016).

In summary, on the one hand the discourse of 21st century learning constructs the possibility of a movement towards personalised, student-directed, skills-based, competency-based approaches. The 21st century learning discourse could seem to be politically hegemonic in that internationally and nationally it is informing the development of competency-focussed curricula, digitally mediated schooling, the re-design of physical classroom space, and a growing emphasis on flexible, performance-based or standards-based assessments. Yet according to my own observations and to findings in literature, these changes seem to be in tension with some ways of teaching and learning in science and some aspects of some high stakes assessment in senior secondary school.

## 1.7 Framing the research

Adopting a social constructionist stance, the aim of this research is to employ constructionist theory and thinking tools to consider ways in which the discourse of 21st century learning might play out in senior secondary science in the context of high stakes assessment in FLS. The focus is on how teachers and students are positioned, and if and how they might be repositioned in this setting to produce new possibilities for science teacher and learner identities.

I chose science education as a curriculum context for this research because prior to my work in teacher education, I was a teacher of science, chemistry, biology and mathematics. I understood and was passionate about science education as a way of investigating and understanding the physical and material world. As a past science teacher, I remembered my laboratory as my domain. I enjoyed taking students on a science learning journey, with me firmly in the driver's seat. I wondered how I would have felt and acted, had I been required to make the shift to 21st century initiatives such as flexible learning spaces. Therefore, secondary schools with flexible science learning spaces which incorporated wired and wireless technologies provided a compelling context for the aspects of physical space and digital technologies in this research. The NCEA as the official national secondary school qualification in Aotearoa New Zealand provided the context for high stakes assessment within the study.

**Overarching research question**

Because I was interested in a framework of elements of digital technologies, physical space, assessment, and curriculum, and interested in possibilities for the types of teacher and student identities they supported, I asked an overarching question which allowed me to look across the learning environment as a whole:

> *How might the discourse of 21st century learning influence notions of senior secondary science to offer different identity descriptions for science teachers and learners in Aotearoa New Zealand?*

I investigated this question in two phases. Firstly, I wanted to know what *was actually happening* for teachers and students of senior secondary science in FLS. Secondly, I wanted to inquire into possibilities for the *future* in science teaching and learning. Each phase had its own questions and approach.

**Phase one sub-question:**

> *What* **does** *science teaching and learning look like in flexible learning space schools, when teachers and students are focussed on NCEA science assessment?*

Phase one involved case study research to investigate what was happening in NCEA science learning in three FLS schools. The three case studies foreground teacher experiences (Rogoff, 1995) and focus on teacher identities.

Portraiture was also used in this phase. Portraiture is a way of creatively using researcher-voice in storified form to document and present findings (Lawrence-Lightfoot, 1983). In this study, a portrait was developed by looking across the three cases. Experiences of both teachers and students were foregrounded to present possibilities for teacher and student identities and to craft a portrait of what science learning *might* look like.

**Phase two sub-question:**

> *What* **could** *science teaching and learning look like in flexible learning space schools, when teachers and students are focussed on NCEA science assessment?*

Phase two involved a collaborative action-research approach which focussed on what science learning *could* look like in FLS, under NCEA. It aimed to provide an in-depth story of what happened for teachers and students over three cycles of collaborative action research when 21st century science learning was positioned as personalised and inquiry-based. This phase focusses on the experiences of teachers and students (Rogoff, 1995) to document the possibilities for identities that were offered and that were taken up.

## 1.8 Overview of thesis structure

This thesis is organised into nine chapters. **Chapter one** has introduced the idea of 21st century learning as a discourse. This chapter has introduced the research problem, aims, and questions, and has detailed my professional experiences which led to the development of this study.

**Chapter two** positions the study theoretically. It describes how social constructionist notions informed the design, enactment, and analysis of the research. It introduces and explains constructionist ideas about discourse, positioning in discourse, and identity as a way of theorising and making sense of what is happening to science education and to teachers and students in 21st century contexts. It documents ways in which social constructionist theories and parallel or related theoretical orientations have been used to understand issues associated with teacher and student identity and science education reform.

The way the discourse of 21st century learning plays out in secondary schooling is explored in this research within a framework of four central elements of a learning environment. **Chapter three** reviews literature relevant to this framework. It details how flexible spaces, digital technologies, curriculum, and assessment each work to produce different possibilities for teaching and learning which might impact teacher and learner identities. In Chapter three I argue that underpinning the discourse of 21st century learning is a commitment to personalised, self-directed learning. **Chapter four** therefore narrows the focus to review literature on personalised learning as a key aspect influencing possible 21st century teacher and student identities, then examines the use of inquiry as a vehicle for personalising science learning.

**Chapter five** presents the research methodology and methods informed by constructionist theory and thinking tools adopted in this project. Details of research design and methods for the phase one case studies and portraiture and for phase two action research are described. Approaches to analysis are explained. Strategies for establishing trustworthiness of data collection and analysis are explained and ethical considerations outlined.

Chapters six to eight report research findings. **Chapter six** presents data and reports findings from three case studies conducted in phase one to show what science learning *looked like.* Chapter six also presents a cross-case synthesis using the technique of portraiture to provide an overall picture of what science teaching and learning *might* look like. The case studies and portrait bear directly on the phase one contextual sub-question. **Chapters seven** and **eight** present data and outcomes from three cycles of action research in phase two. These chapters bear directly on the phase two sub-question which asks what teaching and learning in science *could* look like.

Interpretive discussions conclude the sections and subsections of chapters six to eight. They present a deeper look (Leinhardt & Steele, 2005) at what *is* happening and what *could* happen in science learning in terms of analysing possibilities for teacher and student positions and identities in discourse. These interpretive discussions pertain to the overarching theoretical research question.

In **chapter nine** I step back to draw together ideas from the interpretive discussions from both phases of research to respond to the overarching question of how the discourse of 21$^{st}$ century learning plays out in senior secondary science education in Aotearoa New Zealand to offer new identity descriptions for teachers and learners. Limitations of the study are outlined and major implications for research, policy, and practice are discussed. The final section of chapter nine summarises the major contributions of the research.

# Chapter two: Theoretical positioning

Kenneth Tobin, a recognised science educator, scholar, and author, states with elegant simplicity that "theories change the way we experience the world" (Tobin, 2015, p. 4). In this chapter, I introduce my understanding of aspects of social constructionist theory which underpin and inform this study (section 2.1). I explain in philosophical and methodological terms how this theoretical orientation influenced the way I experienced this research and how it informed the research design and analysis (Hammersley, 2012a; Koro-Ljungberg, 2008; Tobin, 2015). The ways in which I understand constructionist concepts of discourse, positioning, and identity to be interrelated are central to the approach taken in my theoretical analysis, and in section 2.2 I explain these ideas. Firstly, I explain the connection between language and discourse. Secondly, there are different methodologies associated with a social constructionist theoretical stance which can be distinguished by various types of macro or micro discourse analytical approaches (Burr, 2003; Willig, 2008). I introduce and explain these ideas. Thirdly, the notion of identity is introduced which ties together macro discursive and micro positioning analyses. Finally, I clarify my own social constructionist theoretical stance. In section 2.3, I identify foci for the study of discourses in this study.

The subsequent section takes the form of a brief literature review (section 2.4) where I survey previous use of social constructionist interpretations and analytics in educational research, and specifically science education. The notion of identity is important in this research, and only a few studies were found that directly linked social constructionist theory and science identity. Therefore, I also review studies informed by sociocultural theories to understand issues associated with teacher and student identity and science education reform. Section 2.5 concludes the chapter.

## 2.1 Social constructionism

A paradigm is a conceptual framework or research orientation; a way of looking at research objects or phenomena. It is associated with specific methods of research design, construction or description of data, and explanation of findings (Denzin & Lincoln, 2013; Johnson & Onwuegbuzie, 2004; Trifonas, 2009). In other words, the philosophical assumptions associated with a paradigm set an ontological, epistemological, and axiological frame around the research process, which in turn influences the type of truth claims that can be made (Markula & Silk, 2011). Therefore, the paradigms and theoretical perspectives that shape the research process must be explicitly represented.

While there are a number of paradigms and categorisations of paradigms, in this study I use the categories set out by qualitative research approaches and focus on the interpretive paradigm (Donmoyer, 2006; Lather, 2006). The interpretive paradigm is located in the language of understanding, insight, and uncertainty. It embraces naturalistic and qualitative approaches. The interpretive paradigm is a subjective rather than objective undertaking (Denzin & Lincoln, 2013). It assumes that the social world is complex, and that human behaviour "cannot be defined in reductionist terms" (Cohen, Manion, & Morrison, 2011, p. 12). Therefore, interpretive research acknowledges the role of context and focuses on understanding participants' meanings. Human activity must be understood in situ, using "thick descriptions" from participants' perspectives (Borko, Liston, & Whitcomb, 2007, p. 5). The influence of the researcher cannot be removed (Markula & Silk, 2011). This means that the researcher, in the paradigmatic research decisions and interpretations they make, constructs a particular truth claim from the data that they collect. The questions guiding this research focus on the subjective, institutional, and personal factors which influence teacher and student identities where they are situated within a complex schooling environment. This makes the interpretive paradigm appropriate.

Located within the interpretive paradigm, social constructionism has strong connections to poststructural theories but also resonates with phenomenological and ethnomethodological methodologies (Gergen & Gergen, 2015; Holstein & Gubrium, 2011). Studies which embody social constructionist notions are often considered to be grounded in the work of sociologists Peter Berger and Thomas Luckmann (Burr, 2003; Gergen & Gergen, 2015). In their book *The Social Construction of Reality* (1966), Berger and Luckmann present a view of people existing in a social world which is continually created and sustained by social practices. This then becomes their objective reality, which people must act on and act within (Berger & Luckmann, 1966/2016; Burr, 2003). Michel Foucault is often awarded a pivotal position in the origins and theoretical advancement of social constructionist theory due to his contributions around notions of power and the archaeology of knowledge, and of the origins of discourses (Burr, 2003; Weinberg, 2008). But it is important not to attribute all developments to Foucault. Other Western scholars associated with the philosophical foundations of constructionism who went before Foucault, and from whom he drew, include GWF Hegel, Karl Marx, Ludwig Wittgenstein, Max Weber, and Martin Heidegger. Following on from Foucault and often drawing upon Foucault's ideas, other scholars including Bronwyn Davies, Wendy Hollway, Ian Parker, Jonathan Potter, John Shotter, Margaret Wetherell, Vivien Burr, and Carla Willig have contributed to the upswell of different descriptions and applications of social constructionist research methodologies. Others who might refer to themselves or to aspects of their work within constructionist frames include Kenneth Gergen, Mary Gergen, Rom Harré, and Luk van Langenhøve. I rely upon the theories and scholarship of these constructionist thinkers, philosophers, and academics, as well as others, in my research.

As I position this study within social constructionist theory I am introducing a language with which to talk and think about the social phenomena I observe (Hammersley, 2012a). As such the social constructionist orientation is an epistemic voice which speaks *to* and *through* this study, and so informs methods, analysis, and findings. I will now introduce key aspects of social constructionist theory which informed this research.

## 2.2 Social constructionist thinking tools used in this research

### *2.2.1 Language and discourse*

As introduced in chapter one, social constructionist theory conceives of 'discourses' as specific clusters of language, social practices, or knowledge that together produce, construct, or represent objects or events in certain ways (Burr, 2003, p. 64). From a social constructionist viewpoint, reality as we experience it, and the knowledges and ideas we have about the world are socially constructed in and by language (Burr, 2003, 2015; Willig, 2008). The distinction between knowledge and *knowledges* is significant. As all experience is mediated through unique historical, cultural, and social frames that are particular to every individual (Willig, 2008), there cannot be one single reality or way of knowing about the world. People are understood as the products of social forces, and their realities are not fixed but are constructed by language, in conversation and in interaction with others. That is, the various realities are produced through discourse (Burr, 2003; Winslade & Monk, 2000). According to Vivien Burr (2015), "discourse is at the heart of social constructionism" (p. 224).

Foucault states that discourses are "practices which form the objects of which they speak" (1972, p. 49). Hall (2001) and Burr (2003, 2015) argue for this Foucauldian interpretation of discourse as being 'constructive', in that discourse both defines and produces the objects of our knowledge. Hall (2001) writes, "(Discourse) governs the way that a topic can be meaningfully talked about and reasoned about. It also influences how ideas are put into practice and used to regulate the conduct of others" (p. 72). According to Burr, discourses regulate our knowledge and understanding of the world: "discourses, through what is said, written, or otherwise represented, serve to construct the phenomena of our world for us, and different discourses construct these things in different ways" (2003, p. 65). Hence discourses categorise and construct objects, events, and subjects, and act both to allow and constrain possibilities for action (Davies, 1994; Miller, 1994). As an example, 'social constructionism' is a specific collection of academic understandings and terminologies, and constructs ideas about meaning and reality in certain ways, so itself can be recognised as a discourse (Burr, 2003).

I move now to examining the influence of discourse at the macro or structural level, and then at the micro or interactional level, before considering the notion of identity which connects the two.

#### *2.2.2 Discourse at the macro level*

In section 2.2.1 above I explained that language as a precondition for thought, located in discourse, constructs the way we know our reality (Burr, 2003, 2015; Potter & Hepburn, 2008; Potter & Wetherell, 2001). However, it is not spoken language *alone* that produces reality as we experience it. Discourses construct in ways other than speech and action. Discourse can be embodied in physical structures and in institutional policies and texts. These all exert a constitutive force as they work to structure our experiences (Burr, 2003, 2015; Holstein & Gubrium, 2011). Holstein and Gubrium (2011) refer to physical space as constructive when they point out that, "even the design of buildings…reveals the social logic that specifies ways of interpreting persons and the physical and social landscapes they occupy" (p. 344). Timetables, assessment schedules, social hierarchies, curriculum goals, and physical learning spaces all powerfully affect what teachers and students can do and aspire to do in practice (Burr, 2015). In this thesis, macro-level policies and structures to do with curriculum, assessment, physical spaces, and digital technologies together are seen as contributing to the construction of institutional realities which teachers and students experience and act within.

### *2.2.3 Discourse at the micro or interactional level: Positioning and repositioning*

The notion of positioning introduces the idea of discourse at work at the micro or interactional level. Positioning in discourse, or discursive positioning acknowledges both the constructive force of discourse as well as the capacity for diverse individuals to take up various positions within a discourse (Davies & Harré, 1990; Harré & van Langenhøve, 1999). In other words, people are simultaneously positioned by discourses and draw on discourses to position themselves and others within specific interactions (Harré & van Langenhøve, 1999, p. 225). Within social constructionist theory, all speech, actions, and interactions are acts of positioning (Burr, 2003). In fact, Burr (2003) would argue that people "cannot avoid subject positions, the representations of [them]selves and others that discourses invite. [Their] only choice is to accept or resist" (p. 111).

Positioning in discourse may be conscious and intentional (Kecskemeti, 2011). Positioning occurs in every conversation or action where one wants to express one's agency (the ability to exercise choice) (Crawley, 2014), put across a particular point of view, or narrate a personal history of events in a certain way, for example, in telling an autobiographical story (Harré & van Langenhøve, 1999). However, many discourses are invisible, working 'behind the scenes' to tacitly position teachers and students and to channel their actions and communication in every moment (Winslade & Monk, 2000). With numerous discourses surrounding any one object or event, and with each discourse constructing or representing objects or events in different ways and attracting different rights, duties and obligations (Harré, 2012; Harré & van Langenhøve, 1999), discourses are sometimes characterised as either 'dominant' or 'alternative'. The most powerful or dominant discourses are often those that are unseen yet present themselves as ‘the only way’. Their strength can make challenges to them seem unwise (Carabine, 2001; Willig, 2008; Winslade & Monk, 2000).

In a discourse which could be labelled ‘traditional schooling’, teacher-led, transmission approaches are often seen as most expedient in preparing students for high stakes examinations in which school communities, including teachers and students, are all invested under various accountability regimes. If teachers and students enact their rights and duties (Harré, 2012; Harré & Slocum, 2003) within a traditional schooling discourse, it is a teacher’s duty to teach, deliver curriculum knowledge, and prepare students for examinations. For a teacher taking the position of expert, this might include a resultant positioning for students as ‘empty vessels’, whose duty it is to learn the information presented to them. The teacher would be accorded speaking rights in that they would be entitled to speak and have students listen.

On the other hand, when embracing the Māori principle of ako, a teacher might position themselves sometimes as teacher and sometimes as learner, expecting that students bring their own knowledges to the learning community, and that they will contribute their knowledge and work cooperatively. This stance positions students and teachers into different learning and knowledge relationships compared with more traditional teacher-as-expert styles. Further differences could be expected in personalised learning environments where students take the lead and make learning choices (Benade, 2017a; Bevan-Brown, McGee, Ward, & MacIntyre, 2011; Deed et al., 2014; Entwistle, 2005; Prain et al., 2013). All in all, the roles of ‘teacher’ and ‘student’ are complex and dynamic. At any moment, teachers can position themselves and are multiply positioned within different schooling discourses as coach, expert, caregiver, counsellor, or even as enforcer of school policies and rules. When students negotiate their identities as learner and peer group member they too are positioned or choose to position themselves into diverse and sometimes conflicting discursive domains (Kecskemeti, 2011).

The option of teachers and students appealing to alternative discourses, or *repositioning*, gives us a departure point for change (Harré & van Langenhøve, 1999). If one way of being or doing within a certain discourse is restricting, then it becomes possible to intentionally reposition oneself by calling upon an alternative discursive frame. For example, it is common to view high stakes assessment as competitive, academic, and examination-based when immersed in a traditional schooling discourse related to achievement, accountability and meritocratic future success. However, it is also possible to see assessment as valuing, credentialing, and acknowledging all types and forms of learning (Wylie & Bonne, 2016).

Thinking in a constructionist frame, it could be concluded that new ‘truths’ about education are continually being constructed by policy, architects, researchers, and think tanks. The discourse of 21st century learning as it is conceived of in this thesis is presented as a way forward for equipping young people with the competencies and capabilities needed in a fast-evolving society. Twenty-first century education initiatives such as those involving a transition to an alternative physical reality of FLS dictate new categories and identities for ‘teacher’ and ‘student’ (Gergen, 2015). Yet there are dominant and well-established, traditional ways of thinking about teaching and learning which can compete with these new truths.

As well as the concepts of discourse at the macro structural and micro interactional (positioning) level, identity is a key concept which will be used to think about how teachers and students can be in certain contexts, and I will now clarify my use of this term.

#### ***2.2.4 Discourse, positioning, and identity***

In social constructionism, the weaving together of multiple positions from the multiple discourse communities within which people are located make up the threads of an individual’s identity (Burr, 2003, p. 107). In this thesis, I refer to the way we act in and on possible discourses of teaching and learning in science as aspects of teacher and learner identity. To emphasise that identities are not fixed entities (McDermott, 1976), and to acknowledge that a teacher can be ‘other’ in contexts outside of those I am focussing on, the term ‘teacher identity’ will be used to signify the sum of available, pedagogical positions which result in the observable performance at a micro level of ‘teacher of senior secondary science’ (Carlone, Webb, Archer, & Taylor, 2015; Taylor, 2001b). In other words, as Taylor (2001b) describes, “identity is something which one *does* rather than *is* (p. 313, emphasis in original). The notion of identity therefore avoids essentialist connotations associated with the construct of personality; identity is conferred or socially bestowed within limitations and possibilities constructed within discourse rather than being any essential quality of a person (Burr, 2003).

For students, the term ‘student identity’, signifies actions and speech acts associated with ways of being a learner in senior secondary science. An example of this is Laws and Davies’s (2000) description of students being coached into making the right behaviour choices at school, where their “recognisability” or identity as “good” students who know when to speak, what to say, and when to be silent depends on this (p. 209). Again, this is not to deny other behaviour and identities within the social milieu of students’ lives both inside and outside of school, but rather a choice to concentrate the research lens on the schooling storyline.

In the next section, by distinguishing between social constructionist and scientific thought and by acknowledging critique of the more relativist social constructionist position I will now more firmly establish my own theoretical stance.

### *2.2.5 A social constructionist stance: Realism versus relativism*

Social constructionist thought in its most relativist stance encompasses the idea that there can be no objective reality outside that which is constructed moment by moment as language, from within a particular cultural, social, or historical context. Our knowledge of the world is always an interpretation: “There is no stable unchanging world or realm of objective truth to which anyone has access, reality is in a constant process of construction” (Walshaw, 2001, p. 472).

Critiques of social constructionist theory often confront the relativist position described above by pointing out that if there are no absolute truths to be known about the world then we are not able to claim, for example, that any one moral standpoint is preferable to another. This relativist stance renders constructionist notions as slippery and ineffectual in any social research which might have critical or emancipatory aims (Burr, 2015; Gergen, 2001; Lock & Strong, 2010). However, it is also this thinking which contributes to social constructionism’s poststructuralist leanings and permits a multiplicity of possible ways of being in any one situation. This means that if one way of talking about or being in any situation is limiting or unhelpful, it can be changed by appealing to and repositioning within an alternative discursive frame.

By contrast, a realist scientific worldview would 'know' the world as tangible, able to be objectively discovered, investigated, and described (Burr, 2015; Elder-Vass, 2012; Gergen, 2015). The power in the truth claims of the natural sciences often rest in their ostensibly uncontaminated objectivity and detachment from that which is subjectively human. Scientific language, scientific methods, and reports written in objective voice seemingly separate the researcher from the subject or object under study and removes the researcher's influence on the data (Restivo & Croissant, 2008; van Langenhøve & Harré, 1999). However, as Restivo and Croissant (2008) argue: "There are things that are true and things that are false about the world, but things are not true and false in very simple non-contextual, un-situated ways" (p. 220). For example, few people would argue that the state of being 'dead' does not exist. Yet constructions of death vary according to cultural or religious belief and in recent years the definition of 'dead' has been constructed scientifically in different ways (Marantz Henig, 2016). Therefore, science, via the social process of discovery and attaching language to phenomena, can be conceived of as socially constructed truth. Science is a representation of reality and scientific truth never becomes the final, only version. Rather, it is "subjective, tentative, deeply contextualised, local, and reliant on human interference, creativity, and imagination" (Melville & Bartley, 2013, p. 172).

Critical realism is a social constructionist stance which acknowledges the existence of a natural world or a physical and material reality which exists independent of our perceptions and socially constructed descriptions of it. Put another way, this stance of ontological realism but epistemological relativism (Burr, 2015, p. 113 after Parker, 1992) accepts that there is a reality which exists outside of discourse, yet our understandings of that world are socially constructed in and by discourse. It is this critical realist stance I take in this research. For example, it is difficult to deny the existence of a new physical reality of flexible learning spaces. However, within a critical realist orientation, it is possible to argue that policies which produce FLS are socially constructed and that the spaces exist as a physical outworking of the 21st century learning discourse. It is possible to argue that the inhabiting of new space constructs and restricts in certain ways, but we must also concede that teachers and students can know the space in different ways and take up different positions within. Burr (2003) describes this position succinctly: "Our social constructions are based on reality as it is actually structured" (p. 96). This view still permits metaphysical or psychological and social domains such as emotions and social conventions to exist purely as socially constructed entities (Restivo & Croissant, 2008). What ties these domains together in this study, whether physical, structural, institutional, material, social/psychological, is the role of discourse in the construction of possibilities for positions and identities.

## 2.3 Identifying discourses in action and tension

There are multiple discourses which could be associated with the construct of 'senior secondary science schooling' (Hart, 2002). A legitimate critique of research involving discourse analysis is that the identification of discourses can merely involve the categorisation of commonplace constructions and occurrences as discourses. This could eventually result in the nonsensical "proliferation of discourses until there are as many as words in a dictionary" (Burr, 2003, p. 175). Yet a contrasting view is that discourses can be useful handles – attached to specific categories and understandings that allow everyone to know what it is that is being talked about. For example, in the process of distinguishing innovative 21$^{st}$ century education ideals from more conventional practice, reference is often made to the notion of "traditional" schooling. This is seen in a brochure promoting the Australian Research Council's large-scale "Innovative learning environments (ILE) and teacher change" project. Project leader Wesley Imms is quoted: "ILEs have been conceptualised and designed to support the move from traditional teacher-focussed instruction, to active competency-based, student-centred ways of working" (Innovative Learning Environments and Teacher Change [ILETC], n.d.). Without explaining exactly what traditional teacher-focussed instruction is, one might conjure a picture of a classroom with an orderly arrangement of desks, and a teacher at the front of the room talking to silent, studious, pupils.

To avoid the aforementioned nonsensical proliferation of naming discourses in this research, I limit the focus to two key discourses. First and foremost, I focus on ways in which teachers and students of science are positioned in the discourse identified as 21$^{st}$ century learning.

Additionally, I recognise the discourse of traditional science schooling. Well-known Australian science educator and academic Russell Tytler (2007) refers to the "resilience of traditional school science". This is where the teacher acts as expert, delivering knowledge to dependent students, and where the emphasis is on:

> conceptual knowledge, compartmentalised into distinct disciplinary strands, the use of key, abstract concepts to interpret and explain relatively standard problems, the treatment of context as mainly subsidiary to concepts, and the use of practical work to illustrate principles and practices. (p.3)

Carlone et al. (2010) reinforce this view:

> …we are all familiar with traditional practices of schooling, which perpetuate the teacher as authority, students as recipients of knowledge, and science as a body of knowledge. In this view, schooling is conceptualized as a form of exchange of knowledge (from teachers, to students) for control (of students, by teachers). (p. 943)

Further, Tytler (2010) and Carlone (2003) suggest that traditional science schooling is strongly associated with structured canonical knowledge associated with the separate science disciplines and note that teachers can strongly identify with their specialist science subject. Traditionally at senior secondary level, the essence of each discipline is represented in a set of abstract and generalisable principles which are often arranged according to increasing levels of conceptual complexity and which translate into the taught curriculum (Avraamidou, 2018; Beauchamp & Thomas, 2009; Bull et al., 2010; Hart, 2002).

Conventional pedagogies which can be linked to traditional science schooling include whole-class teaching, teacher control of content, time, and space (Deed et al., 2014), and positionings of teacher as expert in transmission mode with students receiving and remembering information (Carlone et al., 2010; Melville & Bartley, 2013; OECD, 2013). The notion of personalisation has little place, neither does the notion of learning taking place outside of school or from a source different to the teacher (OECD, 2013).

In differentiating between an innovative learning environment and a traditional schooling environment, Wright (2017) uses the concept of the "paradigm of one" (p. 49). Coined by Maurie Abraham, Principal of a large New Zealand FLS secondary school, this concept "describes the closed nature of traditional secondary school classrooms" and is used "as shorthand for the prevalence of single-classroom, single teacher, single-class, single-subject arrangements in such schools" (p. 49).

The discourses of traditional science schooling and 21st century learning are not necessarily mutually exclusive; neither are they always compatible. For example, both treat the element of assessment in senior school as a collection of meanings that say qualifications are important, that students have a duty to achieve and teachers must help students 'get there' or 'cross the line'. It could be argued, however, that each discourse treats processes of credentialing and recognition of achievement in different ways. Therefore, each produces different possibilities for pedagogies, and different social identities for teachers and students.

This thesis examines ways in which senior secondary science schooling is being constructed and influenced by the discourse of 21st century learning. The traditional science schooling discourse serves as both a prototype and a point of departure (Belli, Aceros, & Harré, 2015; Carlone et al., 2010). Social constructionist ideas of discourse, positioning, and identity will be used to analyse and make visible some aspects of institutional elements which work to produce particular types of science teacher and student, and will consider possibilities, tensions, and challenges moving forward.

In the literature review below, I explain possibilities for new insights that a social constructionist approach offers in this study.

## 2.4 Social constructionism in action

In this section I first canvas studies in education built upon constructionist or related poststructuralist paradigms. I quickly narrow the focus to science education to inform methodology, research design and analytics. There are few studies linking science education and identity which profess to have their epistemological origins in social constructionist thought. I discuss these studies separately and in detail in the paragraphs below (section 2.4.1). However, there is a large body of research associated with the identity of science teachers and students which sits within a sociocultural framing. As the concept of identity is important in this research, I widen the review to include this understanding of science identity and outline how arguments from a sociocultural frame inform this study (sections 2.4.2 and 2.4.3). I point out resemblances to aspects of social constructionist theory and make distinctions between the two orientations.

### *2.4.1 Social constructionism and educational research*

Social constructionism embraces a variety of research approaches in the study of social interactions (Drewery 2005; Harré, Moghaddam, Cairnie, Rothbart, & Sabat, 2009; Kecskemeti, 2011; Ritchie, 2002; Sabat, 2003; Winslade, 2005). Positioning theory has informed studies of classroom interactions in contexts such as gender and gender equity (Baxter, 2002; Clarke, 2006; Creese, Leonard, Daniels, & Hey, 2010; Ritchie, 2002), literacy and language learning (Lassonde, 2006; Martin-Beltran, 2010; Vetter, 2010, 2013; Yoon, 2008), and disability (Baines, 2012). Studies have also informed issues related to student identity and behaviour (Collins, 2011; Davies & Hunt, 1994; Davies & Munro, 1987; Drewery, 2004; Drewery & Kecskemeti, 2010; Kecskemeti, 2011; Laws & Davies, 2000; Ryan & Morgan, 2011).

There is recognition in social constructionist literature that teacher positioning of students at the micro level can affect students' social interactions and participation in the classroom. Martin-Beltran (2010) argues the need for educators to "orchestrate learning contexts that re-position students as proficient language users" (p. 257), noting the "power that teachers' subtle, everyday discursive practices have to shape students' language learning" (p. 272). Similar to this is Vetter's (2013) assertion that teacher talk is a "powerful tool" which can be used to position students as members of a literacy community (p. 179). Rex (2000) observed a teacher enacting interactional inclusion by making particular "discourse moves" as they assisted a student to re-enter a mainstream classroom following a period of segregation in a special education classroom (p. 329). Clarke (2006) used constructs of positioning and power to analyse girls' positioning of boys in literature circle discussions. Clarke found that conversations in the literature circles were linked with "larger storylines of class-specific gender roles" (p. 55), which empowered girls' literacy development, whilst disempowering boys. By better understanding positioning, Clarke reasoned that teachers could take a proactive role in assisting students to resist undesirable positionings and create new positions.

Data collection techniques for educational research employing a social constructionist frame are often focussed on generating language data for analysis. Audiotaped observation of classroom practice along with interview can be situated within case study approaches. Yoon (2008) used audiotaped classroom observation and interview within case study research to understand complex classroom dynamics using a positioning theory lens. Yoon established that teachers' pedagogical approaches and interactions with English language learners (ELL) were dependent upon how they saw themselves as teachers. ELL students were either positioned by teachers as "powerful and strong" or "poor and powerless" (p. 515), with this having a corollary effect upon teachers' expectations of student participation in the learning.

Constructionist studies have demonstrated the value of developing teachers' understanding of positioning theory in the offering of agentic identities to diverse learners (Ritchie, 2002; Sosa & Gomez, 2012). Sosa and Gomez (2012) used data drawn from observation and interviews of ten teachers in one urban high school. They analysed teachers' discourse from the position of 'effective teacher' and the relative positioning of "Mexican American working class" students (p. 594). Findings suggest that effective teachers positioned students as individuals who were capable of academic achievement and who were fully responsible for their own school success. This positioning of students contradicted deficit-based views and negative assumptions that students fail because they lack motivation and intellectual ability. These findings are relevant to my own research because they demonstrate the effect of differential teacher positioning of students. Effective teachers were those who accorded students the right to construct identities as decision-makers and drivers of their own learning (with guidance and support) and who communicated the expectation that students would do so. Ritchie (2002) captured student-to-student interactions in the context of science group work in year six students. Drawing on Foucault's notions of power as distributed and Harré and van Langenhøve's positioning theory, Ritchie considered students' social positioning and the ways in which "gender, status and power relations intersected" (p. 35). Ritchie concluded that teachers can often be unaware of the complex social interactions that occur between students in peer groups. The author develops ideas of contested positioning and repositioning in peer groups, arguing that greater awareness of positioning theory might help teachers to assist students who face unproductive conflicts in groups to navigate these as they attempt to negotiate opportunities for learning in science. Ritchie suggests that positioning theory could be useful as a tool for helping teachers to understand students' social interactions.

Writing about assessment of learning, Wortham and Jackson (2008) in their account of the usefulness of constructionist approaches for education draw on the example of student identity as a socially constructed "assessed statistic" (p. 115). Education discourses bestow value on certain types of learning, and students who do well in school assessments are those who are immersed in discourse communities which align themselves with the type of learning available. Wortham and Jackson argue that this serves to perpetuate the "social stratification" of those who can 'do school' and those who can't (p. 117). This raises the question: What should or could science schooling look like if it is to offer meaningful learning experiences for diverse learners? Furthermore, especially in senior school, what about *assessment* of evidence of learning? One would expect the answer to this question to be different for individuals who have been variously immersed in different discourse communities, making a one-size-fits-all approach not appropriate. In turn, this presents the not insignificant challenge of executing a personalised programme which can be legitimately, rigorously, fairly, credentialed.

Søreide (2006) understood a narrative construction of teacher identity based on poststructuralist and discourse theory, combined with theories of narrative identity (p. 527). Analysis of teacher narratives collected during interviews about everyday life in Norwegian public elementary schools identified various subject positions which contributed to identity constructions, for example, "the creative and innovative teacher" (p. 537). Teacher identity within a poststructuralist frame was presented as multidimensional, dynamic, constructed, and formed from the institutional "identity resources" (p. 541) available. Søreide acknowledged teachers as active agents in their own lives but also the concomitant regulatory effect of dominant education discourses such as accountability and professionalism in the process of identity construction. This approach is pertinent to my study because of the way Søreide uses the concept of identity and the way the author recognises discourses as regulatory and as impacting teachers' practice.

Few studies have focussed on the impact of discourse on science teacher and student positions and identities (Hart, 2002; Martin, 2016; Melville & Bartley, 2013). Martin (2016) used a discursive psychological framework, which is often characterised as having social constructionist underpinnings (Burr, 2003; Willig, 2008), to study student agency in science as a discursive practice. Conversations between three 13-year-old girls which took place during everyday science lessons were audio-recorded. Positioning theory and the concept of agency were used to analyse the girls' participation in the science classes. Martin argued that the students although capable, "failed to engage meaningfully with science" (p. 41), and that compliance, or the act of maintaining the position of 'good student' by answering questions correctly and following the teacher's instructions, limited their agentic participation in the form of giving their own opinions or asking questions.

Narrative methodology within poststructuralist, Foucauldian traditions offered insight into the "constitution of teacher identities that challenge the contemporary discourse of science education" in a study conducted by Melville and Bartley (2013, p. 176). Melville and Bartley identified the dominant, contemporary discourse of science education as that which prioritises the learning of science conceptual knowledge which is divided into separate disciplines. This dominant discourse was depicted as remaining unchanged over the past century and maintaining a focus on preparing young people to enter a science-related career, but as that which is simultaneously discouraging some young people from engaging in school science (Tytler, 2007). Teacher identity in Melville and Bartley's study was treated as self-presentation; produced in and by discourse, and visible in three secondary school science teachers' narrative descriptions elicited in semi-structured interviews. Their chronological narratives showed how over the course of their careers, the teachers came to challenge the contemporary science teaching discourse. Changes were described in terms of discourses, experiences, and emotions as they progressed through their careers. Melville and Bartley argued that all three teachers at the beginning of their careers were socialised into embracing a "singular, traditional, science teacher identity", which was shaped by the conventions of the contemporary science learning discourse and restricted teachers' ideas about what school science should be, who should teach it, and how (p. 184). Melville and Bartley suggest that from a poststructuralist perspective, teacher identity can be considered as not normalized but continuously reconstituted, a position that allowed teachers space to negotiate their relationship with themselves and their students. An opportunity to challenge the contemporary discourse arose from a focus on science inquiry, mandated by the curriculum. Another opportunity for challenge arose when teachers chose to teach from a place of emotional concern for students' success rather than from within the traditional science teacher discourse, with one teacher observing that "Our job is not science: our job is people…I had to devise a way to make it work better" (p. 185).

In a rare application of poststructuralist theory, Hart (2002) used concepts of discourse and discursive relations of power to explore and theorise the social construction of physics curricula. Hart argues that language within discourse is the "the site where reality and meaning are produced" (p. 1068), and that as each discourse constitutes one particular version of reality, the possibility of constructing alternative meanings are simultaneously prevented. Hart presented an auto-ethnographic account of her involvement in the process of writing a new physics curriculum for the State of Victoria, Australia. The aim of the new curriculum was to make physics more accessible for a wider range of students and to improve the quality of learning. However, she concluded that the new course turned out to be much the same as traditional physics courses. Hart accounted for this by identifying and deconstructing discursive practices which she argued strengthened or supported dominant and traditional ways of teaching physics. The essence of the discipline of physics was seen to be structured around a common core of abstract and generalisable principles which needed to be received and understood by students. Hart surmised that this view contributed to holding back the implementation of an alternative, context-based physics curricula.

A discourse of fairness emphasised the idea that all students should have equal opportunity to learn and therefore that all should study and be assessed on the same physics ideas. A discourse of valuable learning prioritised the teaching of the generalisable, transferable, but abstract physics concepts over what was seen as trivial, context-bound learning. Both discourses had the effect of simultaneously advantaging some groups of students who possessed the intellectual ability to understand abstract concepts and perform well in examinations while disadvantaging or side-lining those who did not. Importantly, Hart linked concepts of positioning, discourse, and identity by suggesting that subjectivities are produced as people are positioned in relation to discourse and that identities are formed in relation to this.

Hart acknowledges that her insights in this singular case were influenced by her own positions and preoccupations, and because the discursive mechanisms identified are not necessarily likely to be identified in other contexts, that the conclusions are not generalisable. Nonetheless, I support Hart's view that this application of poststructural theory can prove to be a useful way of illuminating the means by which the constitution of curriculum influences or governs individuals at the level of positions and identities constructed for teachers and students. Furthermore, I agree with Hart's assertion that the noticing of discursive practices more generally might identify "points of resistance found in the gaps and contradictions between discourses" (p. 1074) when attempting to initiate educational change in an established institutional system.

The inter-related concepts of positioning and discourse in the studies reviewed above are ideas that inform and underpin my study. In addition, ideas of different identities formed within different discourses are germane to the thread running through this study of a repositioning of teachers and students within a 21st century reconstruction of education.

There is a large body of literature associated with science identity which is theorised within a sociocultural frame (e.g. Avraamidou; 2014, 2016; Azevedo, Martalock, & Keser, 2015; Danielsson & Warwick, 2014; Scott, Mortimer, & Aguiar, 2006). As there are resemblances between sociocultural and social constructionist understandings, I will now examine sociocultural studies of science identity.

### *2.4.2 A sociocultural view of discourse and identity*

A sociocultural view seems to share some similarities to social constructionist theories when referencing terms such as discourse and identity. Grounded in Vygotskian (1978) and Bakhtinian (1986) traditions, sociocultural theory sees language as shaped in historical and cultural environments and sees learning and development as situated and context-specific (Azevedo et al., 2015; Danielsson & Warwick, 2014, 2016; Scott et al., 2006). Similar to notions of macro and micro constructionism (Burr, 2003), prominent socioculturalist scholar James Gee (2000, 2014) distinguishes between big 'D' and little 'd' discourses, where big 'D' takes the macro, institutional view and little 'd' discourses refer to micro-interactions or language in conversation. According to Gee, Discourses are about "combining language, actions, interactions, ways of thinking, believing, valuing, and using various symbols, tools, and objects to enact a particular sort of socially recognisable identity" (2014, p. 222).

This representation of Discourse as ways of "thinking, believing and valuing" is different to a constructionist view and could seem to suggest a more essentialist psychology by positioning the origin of 'identity' inside some sort of core substance or character of a (socially located) person who then "pulls off" (Gee, 2014, p. 52) or enacts an available Discourse. A social constructionist would argue a slightly different standpoint – the discourses we are immersed in and to which we have access provide the language, symbols, tools, and objects from which our thoughts, beliefs, and values, and therefore our identity, are constructed. This "top down" constructionist view does leave little room for teachers and students as social agents to respond and make decisions outside of positions they are offered and becomes part of what Burr (2003) terms the "agency/structure debate" (p. 182). However, accessing the concept of discursive positioning, where teachers and students have the ability to take up or resist positions in discourse or to appeal to an alternative discourse, leaves some provision for personal agency in this respect (Burr, 2003; Harré & van Langenhøve, 1999).

The notion of identity as an active performance is commonly associated with sociocultural frames (Carlone et al., 2015; Gee, 2000) and is widely accessed in reform-based science research (e.g. Carlone et al., 2010; Carlone et al., 2015; Danielsson & Warwick, 2014). Similar to a social constructionist view, identity is conceived of as a multidimensional construct; not stable, but socially situated and fluid depending upon which category an actor is affiliated with or situated within (Avraamidou, 2018; Boaler & Greeno 2000; Danielsson & Warwick, 2016; Gee, 2014). For example, socioculturalists Danielsson and Warwick (2014) depict identity within Discourse as a recognisable quality, an ongoing and performative process of "a particular type of 'who' engaged in a particular type of 'what'" (p.

108). Again, the phrase "a particular type of who" suggests a type of essentialism (Burr, 2003, 2015) where different aspects of identity exist internally, as part of 'who' a person is. To transport identity into the social constructionist frame, it must not be conceived of as any essentialist representation of 'self', or 'personality' which is possessed by or located inside an individual as some intrinsic, unchangeable quality (Harré & van Langenhøve, 1999). In other words, a social constructionist conception of identity acknowledges the milieu of unseen background discourses that speak a person into different positions, but also focusses on that which is visible and changeable in their performance and action through repositioning (Burr, 2015; Gergen, 2015; Harré & van Langenhøve, 1999; Kecskemeti, 2011; Melville & Bartley, 2013; Søreide, 2006).

Keeping in mind the differences and distinctions between sociocultural and social constructionist theories, there are some science education studies which rely on a sociocultural framing and which use forms of discourse analysis that are relevant and add insight to my research. I review some studies below.

#### *2.4.3 A sociocultural view of science identity*

Azevedo et al. (2015) used conversation analysis (at a micro level) within case study research of whole-class interactions to theorise a link between specific approaches to science learning and epistemological discourse practices, arguing that different types of activities recruit characteristic forms of discourse. Seeing "language as a primary medium through which participants in a setting construct and reconstruct their joint activity and make sense of their collective goals" (p. 285), the researchers adopted a sociocultural approach to "frame activity and discourse as mutually constitutive" (p. 309). They argue from their findings that different activity types generally supported specific sets of conversational (d)iscourse practices, such as describing and explaining in design-based activities or arguing in scientific argumentation activities. The authors also claim that overlapping discourse practices show different characteristics, for example, arguing is slightly different across design-based and scientific argumentation activities.

Tan and Calabrese Barton (2008) use Gee's conception of identity to define students' science identity: "a science identity demonstrates competent performance in relevant scientific practices and requires a student to both recognize herself and get recognized by others as a ‘science person’” (p. 570). The authors discuss the transformation of a sixth-grade student from marginalised member of a science class to highly valued and successful science learner. Findings from a year-long ethnographic case study were that interactions with teacher and peers in whole class and group settings offered the student different affordances for identity formation, especially as they positioned her as one who could and would be successful in science. They argued that the student’s science identity was context dependent and that both her peers and her teacher played an important role in the transformation.

Scott et al. (2006) drew upon a sociocultural perspective of teaching and learning to analyse discursive interactions and meaning-making in high school science classrooms. They explored the way in which shifts between authoritative and dialogic approaches evolved as a teaching sequence proceeds. The authors used examples of teaching episodes to demonstrate convincingly that the process of switching between authoritative (instruction and information) and dialogic discourse (problematising, questioning including initiation-response-evaluation question-answer chains, and discussion) is a necessary and predictable aspect of teaching which supports meaningful learning of scientific conceptual knowledge. Pertinent to my research questions is the positioning of students and teacher within the study. The teaching episodes took place in a whole-class teaching format, calling on a teacher-as-expert who was firmly in the driver’s seat of the learning journey. Science was positioned as a structured, knowledge-based subject and as such, it was possible to learn in science only with the guidance and superior knowledge of the teacher (p. 622). I argue that the teacher-led sequences which were structured within authoritative and dialogic episodes are more congruent with the traditional science schooling discourse and that these practices could possibly have less strength or relevance within alternative schooling discourses. This argument again sets up questions to do with constructions (or reconstructions) of science teaching and learning in this study.

Reform-based science teaching has been associated with a focus on fostering scientific literacy with deep understanding of fewer foundation concepts. This is differentiated from the discourse of traditional science teaching and learning, which focusses on a remembering and regurgitation of many scientific facts

(Carlone et al., 2010; Danielsson & Warwick, 2014). Reform efforts also focus on ensuring that science learning is relevant to students' own life experience and knowledge. Science as inquiry is central to reform and to helping students understand how scientific knowledge is produced (Carlone et al., 2010; Saka, Southerland, Kittleson, & Hutner, 2013).

In a comprehensive review paper examining how the construct of science teacher identity has been conceptualised in studies of reform-based science education, Avraamidou (2014) cited evidence suggesting that "much of the difficulty in enacting reform is internal to the teacher, including teacher beliefs and values related to students, teaching, and the purposes of education" (p. 167). Thus, Avraamidou suggests that teachers need to be supported into viewing themselves as reform-minded. Saka et al. (2013) also suggests that issues to do with enacting reform-based science are associated with teachers' knowledge, beliefs, values, self-efficacy, and views about science teaching and learning (p. 1227). This essentialist tendency to situate any inertia for change within the individual teachers themselves in the form of personal views or beliefs leaves them to shoulder the burden for reform (Belli et al., 2015; Carlone et al., 2010) and positions them as unwilling to take on new identities in science education. In comparison, constructionist understandings support notions of teacher identity as simultaneously constructed and constrained within and by discourse yet afford an individual the opportunity to take up or reject positions within discourse.

Some sociocultural studies of reform-based science teaching and learning employ ideas of teacher identity to foreground ideas of 'trapped-ness' in unmoving discourses. Danielsson and Warwick (2014) used Gee's sociocultural framework to analyse the ways 11 student teachers negotiated their emerging identities within intersecting discourses of science and primary teaching, as evidenced in teachers' talk about becoming teachers (p. 292). A reform-based science teacher identity was projected as harder to embrace compared to the more easily accessible, traditional, didactical role. The authors contended that student teachers are especially vulnerable because judgements of their suitability to enter the teaching profession are made on their "competent and convincing" performance of recognisable 'teacher' positions (p. 299). This conclusion is interesting from a constructionist viewpoint – a recognisable teacher position already exists in discourse communities which student teachers have previously inhabited, and teachers are possibly teaching as they themselves were taught. The magnetism of dominant, established ways is visible here. As poststructuralist scholars Davies and Hunt explain, it is difficult to escape the "structural, generally invisible aspects" (1994, p. 389) of some powerful discourses, of which traditional schooling could be an example.

Carlone et al. (2010) invited "reform-minded" teachers to consider what it takes to teach in ways which contest the powerful "traditional schooling Discourse" (p. 944). They accessed Gee's notion of 'capital D' discourses to argue that traditional science schooling discourses involving knowledge exchange are always present and exerting an influence, even on reform-minded teachers. The authors depict a "complex interplay between structure and agency, falling in line and rebelling, being a 'good teacher' as traditionally defined and transforming the definition of 'good teacher'" (p. 945). They borrow the elegant metaphor of "tempered radicals" (p. 943 after Meyerson, 2001) to portray the reform-minded teachers' balancing act. Significantly, they observe the effects of powerful institutional realities which "authorise or sanction certain ways of acting" (p. 945), such as the continued emphasis on high stakes testing, which the authors claim tend to bolster the dominance of traditional science teaching and learning discourses.

Worth noting in Carlone et al.'s study is the positioning of participants at the recruitment and consent stage, as I suggest that this perhaps influenced the nature of the data collected during the ethnographic interviews. In enquiring what it would take to 'teach against the grain', selected teachers were overtly positioned in their invitational letters (included in the Appendices of the article) as innovative, excellent, a rare find, the chosen ones (p. 962). Naturally, the teachers took up this positioning with alacrity, seemingly enjoying being positioned as boundary-pushers and 'different to most'. I contend this contributed to the third order positioning (Harré & van Langenhøve, 1999) of un-chosen colleagues as stick-in-the-muds and to the associated story of a struggle to 'teach against the tide'. What if the teachers had been positioned more blandly at the outset? Nevertheless, this study highlights the strength of the traditional schooling discourse as held in place by powerful, time-honoured institutional policies and practices, and hence the difficulty of stepping outside of this when embracing more transformative teaching and learning ideals.

## 2.5 Conclusion

This thesis examines ways in which senior secondary science schooling is being constructed and influenced by the discourse of 21st century learning. In the studies reviewed above, both sociocultural and social constructionist understandings of identity and positioning have acknowledged the dominant and regulatory effect of the traditional science schooling discourse which emphasises science as a body of abstract conceptual knowledge to be delivered by an expert to dependent students. Whilst it would sometimes seem difficult to overcome powerful, traditional, institutional schooling discourses to create momentum for change, it may be possible to find openings for navigating the reconstruction of education within 21st century frames by thinking about ways in which different institutional elements work to construct different possibilities for pedagogical action. These different possibilities then result in teachers and students experiencing themselves and performing as certain types of science teacher and learner. The construct of identity is used in this thesis to signify this observable performance. A critical realist, constructionist perspective has been explained as productive in that it exposes discursive constraints within dominant education policies and practices while simultaneously counteracting essentialist notions of identity which act to confine teachers and students within these (Lock & Strong, 2010; Weinberg, 2008; Wortham & Jackson, 2008).

The next two chapters review literature within the framework of four institutional elements. Chapter three shows how flexible spaces, digital technologies, curriculum, and assessment impact ways in which teachers and students can practice. Chapter four reviews literature on personalised learning as a key aspect influencing 21st century teacher and student identities and examines the use of inquiry as a personalised learning approach for science.

# Chapter three: A framework for a 21st century learning environment

In chapter one, I identified four interconnected elements of a learning environment as a framework within which to examine the ways the discourse of 21st century learning might play out in New Zealand secondary science schooling. The four main sections of this chapter review literature associated with each of these elements. Flexible learning spaces are first discussed as a physical outworking of a 21st century learning policy environment (section 3.1). Next, the impact of digital technologies on teaching and learning is considered (section 3.2). Sections 3.3 and 3.4 examine current views of curriculum and assessment with an emphasis on Aotearoa New Zealand.

As the context for the research is science learning in New Zealand, attention is focussed on literature involving New Zealand education, although the review includes research conducted in international contexts where applicable. Because the field is emerging and political, references to national and international policy and position papers and some media commentary are also included. Again, attention is directed at science education policy and studies of science learning where possible, however, the review also canvasses studies in other subject areas.

## 3.1 Flexible learning spaces

In this section, I explain New Zealand education policy directions which promote the move to FLS. I also show that while this move is positioned as part of innovating the learning environment, it is not a new initiative. I highlight perceived benefits to teaching and learning of FLS, which are often discussed in literature as being compatible with personalised learning approaches. I then balance this with two counter-arguments related to issues of teacher transition and adaptation. I argue firstly that the move to FLS is not always wanted, welcome, or perceived as beneficial by some teachers and principals who are expected to make the shift, and secondly, that while new spaces offer possibilities for innovative practice, the move to new spaces provides no assurance of this.

### *3.1.1 New Zealand policy directions for flexible learning spaces*

One response from OECD countries (e.g. Australia, UK, Singapore, Switzerland) including New Zealand to the question of how to design innovative, effective, learning environments which will enable learners to thrive in the 21st century has been the creation of FLS (Ministry of Education, n.d.-c, 2016a, 2016b; OECD, 2006, 2013, Saltmarsh et al., 2015). The New Zealand Ministry of Education's school property strategy (2011-2021) sets the vision and direction for state-owned school property. It states that to support students as 21st century learners and to prepare them to meet the demands of the 21st century, all schools must have flexible spaces by 2021 (Ministry of Education, 2011). The Ministry's FLS policy therefore requires school boards to adopt the FLS standard as they use property funds for new-builds, rebuilds, or upgrades of teaching spaces (Ministry of Education, 2018a). This mirrors policies and rationales for FLS found in international literature, which similarly state that learning spaces must adapt to meet the diverse needs of 21st century learners and change to align with pedagogical perspectives which have undergone fundamental changes when compared to teacher-centred, 20th century models (Blackmore, Bateman, O'Mara, & Loughlin, 2011; Leiringer & Cardellino, 2011). These policies also align with the OECD's work on innovative learning environments (ILE) (Ministry of Education, n.d.-c; OECD, 2013). While physical space is just one aspect of ILEs, it is one which can support important social and pedagogical opportunities by "encouraging collaboration and inquiry for both learners and teachers" (Ministry of Education, n.d.-c, para. 3). An expectation of departure from traditional ways is clearly signalled: "Traditional approaches to teaching and learning are no longer enough on their own to give children the best education to prepare them for life" (Ministry of Education, n.d.-d, para. 4).

Although the shift to flexible spaces is described in association with innovating the 21st century learning environment and is differentiated from traditional approaches, the first open learning space schools were developed as early as 1940 (Cuban, 2004; Dovey & Fisher, 2014; Historic Films Stock Footage Archive, 2013; Horwitz, 1979; Saltmarsh et al., 2015; Shield, Greenland, & Dockrell, 2010). The idea that flexible learning spaces are required to support the individual needs of 21st century learners is a reproduction of similar ideas about teaching and learning in the open classrooms of the 1970s and 1980s. Students and teachers in these decades were also understood to be living in a "world of exploding information", where each student had unique talents and where it was more important to "find information rather than commit a fraction of it to memory"

(Historic Films Stock Footage Archive, 2013). Other philosophies of teaching and learning in early open classrooms are also comparable to those often projected as 21st century ideals. These include the integration of curriculum areas, individual or small group instruction rather than whole-class instruction, and student choice (Horwitz, 1979). Interestingly, according to Horwitz (1979), research from the 1940s, 1950s, and 1960s showed little difference in academic achievement between students in progressive or open learning environment schools and traditional schools. On the other hand, many students working in the open environment schools scored more highly for descriptive and expressive writing, free drawing and painting, listening and remembering, ingenuity and inventiveness, group cooperation and group problem solving, as well as personal and social skills such as leadership and independence (Horwitz, 1979).

Early open space school initiatives eventually faded and disappeared. Despite the promotion of ideals of peer interaction and teacher collaboration, factors such as "high levels of noise and distraction, occasional disagreements with colleagues and reduced spontaneity in teaching" (Hutchinson 2004, p. 98 as cited in Saltmarsh et al., 2015) ultimately led to the of demise open classroom spaces (Saltmarsh et al., 2015).

### *3.1.2 Benefits of teaching and learning in flexible spaces*

More recently, and perhaps due to advancements in environmental and acoustic design (Shield et al., 2010), researchers and educational architects claim that FLS offer benefits to student learning as well as teacher practice (Benade, 2015a; Byers, Imms, & Hartnell-Young, 2018; Kariippanon, Cliff, Lancaster, Okely, & Parrish, 2018; Nair, 2015; Neill & Etheridge, 2008). The affordances of flexible spaces have been found to produce a synergistic effect which enhances practices of collaborative teaching and personalised learning (Deed et al., 2014; Deed, Lesko, & Lovejoy, 2014; Eiken, 2011; Lovejoy, 2014; Prain et al., 2013; Prain et al., 2014). For example, Cardno, Tolmie, and Howse (2017) describe "innovative modern spaces that enable a collaborative teaching and learning approach in which emphasis is placed on personalising learning to meet each individual students' needs" (p. 122). Wright (2017) claims FLS can be congruent with personalised and inquiry learning, and that the spaces enhance possibilities for curriculum integration and collaborative teaching.

For teachers, a commonly touted benefit is that FLS have the potential to support strengths-based and team teaching approaches (Campbell et al., 2013; Gislason, 2009; Osborne, 2013). One finding from case study research conducted by Gislason (2009) in an open plan American senior high school was that FLS facilitate collaborative, multidisciplinary teaching practices. Campbell et al. (2013) and Osborne (2013) assert that the opening up of classroom spaces contributes to 'de-privatisation' of practice and offers support for teachers in the form of opportunities for the observation of, and reflection on different pedagogical approaches. One example of the opportunities this offers is where two specialist teachers collaborate during an environmental issues project that requires students to publish their learning in the form of a digitally produced poster, with one teacher having skills in digital media and graphic design, and the other, knowledge of science and scientific inquiry (Osborne, 2013).

For students, Bolstad and Gilbert (2012) predict that the "physical unbundling" of classrooms using ergonomically-designed furniture that is easily moved and rearranged will remove obstacles to personalised learning (p. 17). Dovey and Fisher (2014) claim that the flexibility or fluidity of open learning spaces is "a property identified with the multiplicitous practices of student-centred pedagogies" (p. 61). As part of researching the outcomes of the Bendigo Education Plan, Prain et al. (2014) reported on a case study of an implementation of a personalised, differentiated mathematics curriculum using teacher team-work in a rebuilt open-plan learning school. The Bendigo plan was devised to provide more "effective and innovative, future-oriented secondary education" (p. 4) in the city of Victoria, Australia, and involved a range of strategies including the building of four open-plan schools and a focus on curriculum reform to better enable differentiated and personalised learning. Positive outcomes for students in years seven to ten included measurable improvement in numeracy skills as well as increased rates of homework completion and more self-directed learning. Other positive outcomes evident in results from student questionnaires included an improvement in student motivation and desire to learn. The authors concluded that personalised learning depends on "the expertise of teachers to support students' meaningful goal-setting, accompanied by the provision of an engaging curriculum that offers timely strategies and learning experiences to address student goals" (p. 58).

The combination of open, flexible classroom spaces and personalised learning approaches are represented by Deed, Lesko, and Lovejoy (2014) as "personalised learning spaces" (p. 370). Their case study research involving two junior classes (year seven to ten) addressed the question of how teachers can adapt their classroom practice to create personalised learning spaces. They argued that a basis for creating these spaces is an awareness of the affordances of teaching and learning contexts available to the teacher and their students, including virtual, physical, and social space (p. 382). Conclusions were that in a personalised learning space, the teacher must provide the framework for what is to be done, while students exercise some control over how it is done. Both teacher and students negotiate where and when it will be done. They contend that teachers must "operate simultaneous levers of control" as they "loosen, tighten or alter their pedagogical grip" (p. 382) either towards teacher-directed approaches or approaches which permit personalised learning. Each of these approaches present distinct views of who a teacher is and what they do. The authors acknowledged this tension and argued that it was not a matter of preferring one approach above another, but an amalgamation of both.

In another case study, Deed et al. (2014) examined how agency was characterised by teachers and students when personalised learning was facilitated for students (years seven to ten) in open classrooms. Agency was defined as "the capacity to act differently" (p. 67) and understood as a complex mix of choices and reasoning associated with learner investment and motivation. This was facilitated through a "deliberate challenging" (p. 74) of conventional approaches to instead create a culture that supported personalised approaches. Findings from interviews with teachers and students and classroom observations suggested open classrooms "authorised different education practices" (p. 67) and that agency was influenced by a shared understanding (between teachers and learners) of the affordances of open spaces and of personalised learning.

A review of literature related to flexible or open learning spaces found few studies which were directly linked to specific subjects and no studies which were specifically linked to science education. A study by Imms and Byers (2017) employed a single-subject quasi-experimental research design in a recently converted open plan school. One feature of the study was a comparison of mathematics learning of year seven students in an open classroom, which was designed to facilitate student-centred learning, with more traditional classroom setups. Three teachers and their classes spent a term each in the different classrooms. The quasi-experimental design was an attempt to overcome the difficulties presented when attempting to control the many complex variables that affect and impact student and teacher performance. Overall findings were that "physical space does matter" and that a "dynamic and adaptive space" (p. 150) had a significant positive effect on student perceptions of the quality of teaching, the effectiveness, incidence and flexibility of use of digital technologies (p. 145), and students' levels of engagement (p. 148). Imms and Byers claimed these differences were statistically significant when compared to like peers following like programmes in more traditional classrooms. However, even with this research approach it is still difficult to state with any certainty that the environment alone caused this improvement. For example, the teachers may have unconsciously engendered more enthusiasm for learning when in the new spaces compared with the closed classroom space.

### *3.1.3 Challenges for teaching and learning in flexible spaces*

Departing from conventional approaches when teaching and learning in FLS can be challenging as it typically requires a significant shift in teacher practice (Alterator & Deed, 2013; Benade, 2017b; Mulcahy & Morrison, 2017; Saltmarsh et al., 2015; Woolner, Clark, Laing, Thomas, & Tiplady, 2014). Some authors claim redesigned learning environments can be a catalyst for change, requiring pedagogical and social adjustment, albeit with attendant issues and challenges (Cleveland, 2016; Osborne, 2016). Some scholars, for example, Leiringer and Cardellino (2011), warn that redesigned learning spaces do not necessarily result in improved educational outcomes such as student motivation and attainment.

Much of the recent research on flexible or open spaces has highlighted issues to do with teacher transitions and adaptation to new learning environments (Alterator & Deed, 2013; Lovejoy, 2014; Saltmarsh et al., 2015). Lovejoy (2014) argues that adaptation to FLS has proved to be a greater challenge for teachers than for students. Also reporting on outcomes of the Bendigo Education Plan, Lovejoy identified issues such as time demands for planning in team teaching environments, fears that team teaching a large group of students will have detrimental effects on individual student-teacher relationships, and issues of noise and distraction as teachers compete for the attention of specific student groups within the open-plan environment. Dovey and Fisher (2014) go so far as to claim that "just as the classroom reproduces teacher-centred pedagogies, the irreversibility of the open plan can coerce teachers into new pedagogies" (p. 58). Alterator and Deed (2013) also maintain that teachers are called upon to adapt and respond to new physical and virtual environments. They conducted case studies focussing on teacher reactions and perceptions of working in new open plan buildings in junior secondary school. Teacher reactions included collective practice, team orientation, increased interactions and democratisation of authority. Aspects of open space which impacted the work of teachers included flexibility, visibility, scrutiny, and a de-emphasis of authority (p. 328). Likewise, Deed, Lesko, and Lovejoy (2014) (reviewed above) claim teacher adaptation to new open learning contexts involves dealing with uncertain and dynamic interpretations of teaching. They also argue the shift towards personalised spaces "places pressure on teachers to adapt their conventional practice" (p. 370).

According to Benade (2015a), $21^{st}$ century learning discourses "reconstitute" the meanings of education and require teachers to "break with the past" (p. 45). Benade asserts that moves to adopt student-centred approaches which exploit e-learning using digital technologies will challenge teachers to become more reflective and to make shifts in their thinking and practice. As part of a broader programme of study informed by a blend of critical theory and critical hermeneutics, Benade asked participants (teachers, leaders, and ex-school leaders) to suggest attributes of reflective teachers, and to make links between these characteristics and "the imperative to engage in twenty-first century learning" (p. 47). Case studies considered groups of participants in similar roles (teachers and school leaders) across three different primary school environments: one with FLS design, a traditional single-cell design with futures orientation, and a traditional single cell school. The data therefore reflected a spectrum of school contexts and voices. Benade set out principles from literature for reflective practice, including that it should be intellectually unsettling, with outcomes ideally resulting in changed practice with a social justice focus (p. 50). Findings suggested change brought about by reflection on $21^{st}$ century learning was indeed unsettling, and that it did not come easily. Some teachers were pragmatic, accommodating the shift, and others appeared to embrace new styles. However, one principal noted that some teachers (in his view) were anxious about changes associated with 21st century learning because of the demand for assessment-based, data-driven practice, keeping them fixated on a "narrow focus on test results" (p. 51). For others, changing meanings of learning and of being a teacher in 21st century environments meant an obligation to engage in collaborative, de-privatised practice, which in some cases was associated with fear, resistance and a perception of loss of power or control.

Teachers in the studies reviewed above are called upon to adapt, to change, to 'be' new and different people. In some cases, teachers seem to be blamed and something is found lacking in their capabilities or competencies if they do not manage this. For example, Lackney (2008) suggests that many teachers have "poor environmental competence" (p. 134) and observed that teachers in new learning spaces would often continue with more traditional ways through a lack of understanding of how to effectively use space for "pedagogical advantage" (p. 133). In another example, Imms and Byers (2017) note that while "the reconceptualising and inhabiting of new spaces ha(s) moved at an unprecedented pace, teachers' abilities to utilise them efficiently ha(ve) not always matched this growth" (p. 141). These comments seem to ignore very real structural or systemic constraints, and instead position teachers as being at fault through their inability to adapt, leaving them to assume responsibility for successful or unsuccessful reform (Belli et al., 2015; Carlone et al., 2010). Perhaps more realistically, Leiringer and Cardellino (2011) argue that a school is a complex environment and is not complete when the building is. They contend that inevitably there will be differences between intended design and end use of learning spaces.

There are others who also claim that the affordances of flexible spaces provide no assurance of transformation. In the New Zealand secondary context, Bisset (2014) examined the move to flexible spaces in three secondary schools and the changes in pedagogy that occurred as a result. Across three sites, semi-structured interviews were undertaken with seven senior leaders and discussions were carried out with three focus groups. Findings were that *intangible* changes in practice were enabled by a *tangible* shift to new, open, spacious buildings with ongoing access to technology. Tangible changes such as no 'front of room' or integration of technology were seen as tools or enablers for change in teaching and learning, but not a guarantee. In fact, according to Bisset, it is possible to operate in a FLS in a very traditional way; just as a change in pedagogy is possible, if more difficult, in a traditional classroom (p. 46). A significant effect on teaching and learning behaviour in FLS seemed to stem from longer time slots for lessons. Students were unable to sit and listen passively for extended periods, therefore incentivising various alternative practices involving students as active participants, working in groups or on self-directed individual inquiries. Teachers tended to move between small groups as a guide on the side within a community of learners. Participants felt that this was a marked change of practice for many teachers who had taught by being a "front row charismatic entertainer" (p. 75) in previous traditional settings.

Among challenges for FLS identified by senior leaders in Bisset's study were expectations and measures associated with NCEA assessment which continue to nurture more traditional approaches. According to one senior leader:

> We live in an assessment driven world with NCEA and we still have to prepare students for exams. There needs to be a compromise between what we are told to provide as schools and what we are expected to provide and are measured against. It is easier to line kids up in straight rows and they regurgitate information. (2014, p. 68)

Another senior leader when asked if FLS have positively affected learning outcomes for students reported that although "areas such as confidence and independence were being developed in a welcoming, safe environment … based on the NCEA evidence the answer would be 'no'" (p. 70). Bisset's study was not subject-specific, so no conclusions can be drawn about the contexts or subjects within which these statements might have been made. Nevertheless, Bisset's findings signal possible discrepancies between teaching and learning approaches in FLS and NCEA assessment practices in senior secondary school.

It needs to be noted that the shift to FLS is not one which researchers and school communities have automatically embraced. Beliefs about who a teacher should be and how they should practice have influenced one New Zealand school (or the

Board of Trustees and others who speak for the community) to the point of publicly and unapologetically rejecting flexible learning space design. The Headmaster of Auckland Grammar, Tim O'Connor, is quoted in national print media: "Our teaching style is teacher-centred learning," (Johnston, 2015). Auckland Grammar focusses on direct instruction and sees single-cell classrooms as best facilitating this approach. They were able to circumvent Ministry requirements for FLS by accessing private funding to complete (cellular classroom) building upgrades (Johnston, 2015). Even more recently there is evidence that the level of resistance from some school communities to the advent of FLS has not diminished. In a national newspaper article reporting on the negotiation between Macleans College in Auckland and the Ministry of Education over the design of new facilities, Principal Steven Hargreaves rejects FLS and maintains that dedicated cellular spaces better suit the needs of staff and students in specialist subjects. He is quoted: "Consider technology being taught in wide open spaces where one group might be doing something more theoretical and one's doing something with machinery. It'd be difficult to make that work in a way that's good for students" (Keogh, 2018). This disagreement has resulted in a ten year wait for a new science and technology block.

#### *3.1.4 Summary*

Many of the studies reviewed above have shown that FLS can support and facilitate (and in some cases, even compel) teachers and students to engage in more collaborative, student-centred, and personalised approaches to learning. Other studies have demonstrated that while FLS do introduce new *possibilities* for pedagogies, the act of inhabiting redesigned spaces does not automatically translate to changed practice. There seems to be tension between traditional views of teaching and learning and expectations for innovation associated with FLS, with assessment pressures sometimes exerting a normalising effect. No studies were found that focussed on issues related to science learning in FLS, which is the focus of this study.

As discussed in section 3.1.1 above, the shift to FLS is not a new idea, so the question is: Aside from architectural advancements, what is different about *now*? Specifically, what are key particulars of current FLS that might facilitate a meaningful and enduring reconstruction of teaching and learning towards 21$^{st}$

century goals? Perhaps the most fundamental difference between *now* and *then* is the advent of digital technologies. Next, I explore the element of digital technologies as a key aspect of teaching and learning in 21st century environments.

## 3.2 Digital technologies

In this section, I first explain New Zealand education policy which promotes the use of digital technologies and pedagogies. Next, I outline the affordances of digital devices and learning platforms and how they can transform ways that knowledge is used and stored. I then review literature which discusses some of the challenges that digital technologies present for teachers and students in terms of how they are able, or not able, to practice.

### *3.2.1 New Zealand policy directions for digital learning*

In a majority of New Zealand and international schools, including those consisting of conventional classrooms, digital tools, devices, and interactive Web 2.0 and 3.0 platforms are transforming views of learning and knowledge and expanding possibilities for digital pedagogies (Beese, 2014; Benade, 2015b; Erstad et al., 2013; Lin & Bolstad, 2010; Reinsfield & Williams, 2018).

The New Zealand Ministry of Education is riding the digital wave, investing in infrastructure and technical support (The Network for Learning, 2016), and urging school communities to explore how digital technologies might open up new ways that better support teaching and learning (Ministry of Education, 2007a, 2011). In 2012, the Ministry founded the crown company The Network for Learning (N4L) to set up and support a managed network and to provide fully-funded, reliable, ultra-fast broadband to schools. The New Zealand national curriculum stipulates that information technologies are expected to be integrated across all learning areas, with digital technologies also being a key dimension of the technology learning area (Ministry of Education, 2017b). To support teachers to develop effective digital pedagogies within curriculum, investment in hardware and infrastructure is being matched by investment in teacher professional development and online support. For example, support for professional learning is available in the digital technologies-focussed kete on the TKI website titled *Enabling e-Learning* (Ministry of Education, n.d.-b). In the assessment space, the New Zealand Qualifications Authority (NZQA) is piloting online, digital assessments in selected subjects for NCEA qualifications, with the aim of having all NCEA examinations (where appropriate) available online by 2020 (Ministry of Education, 2018b). One rationale for this development is that online assessment would allow learning to be assessed as and when students are ready, rather than the usual practice of sitting all examinations at the end of the year (NZQA, 2018). ePortfolios are being explored as an electronic format for presenting, reflecting on, recording, and sharing students' learning and achievements, and as a platform for receiving feedback and feedforward. These could form a long-term repository which students could carry with them throughout their lifetime learning journey (Ministry of Education, n.d.- b).

### *3.2.2 Benefits of digital technologies for pedagogy and learning*

Digital learning spaces offer new options and opportunities for when, where, how, and with whom, teaching and learning takes place (Conole, de Laat, Dillon, & Darby, 2008; Lemley, Schumacher, & Vesey, 2014; OECD, 2013; Varier et al., 2017; Watson, & Johnson, 2011). In a digital environment, knowledge is no longer static, stored exclusively in books, or seen to be the domain of teachers and schools (Benade, 2015b; Bergmann & Sams, 2014; Bolstad & Gilbert, 2012; Pahomov, 2014; Wright, 2017). Instead, knowledge can be accessed, collaboratively created, used, and shared by students themselves in online global learning communities; any time, place, or physical space (Järvelä, 2006; Tucker, 2017). Digital devices, learning platforms, and Web 2.0 technologies mean is it more possible today than ever before to tailor learning to suit individual pathways or learning trajectories (Benade, 2017a; Järvelä, 2006; Ruano-Borbalan, 2006). Cloud storage, file creation and hosting services enable communication and connection between teachers and students outside of the boundaries of classroom walls or school day. Google Docs, Google Classroom, and Microsoft OneDrive enable collaborative ways of working and knowledge creation. Class webpages provide a publicly accessible repository for group and individual learning. Homework projects can be completed online, individually or using real-time group collaboration. Some would go so far as to argue that digitally mediated learning could render traditional teaching practices redundant (Bergmann & Sams, 2014; Ruano-Borbalan, 2006). Teachers would instead become "online educators" who work with diverse groups of students from different geographical locations, in digital environments (OECD, 2013, p. 194).

Learning can be personalised using digital devices, with students more able to take ownership and make choices. Digital learning platforms offer unprecedented flexibility in curating or customising content, with countless formats available for differentiation (Education Perfect, 2017; Learn Coach, 2018). The ‘pause’ or ‘replay’ button allows for re-visiting learning and working at a slower pace for challenging new learning. Targeted feedback as formative assessment teamed with ‘repetition until mastery’ is a feature of most educational software (Education Perfect, 2015). Flipped learning (Ministry of Education, n.d.-b; Mohamed & Lamia, 2018), blended learning (Bergmann & Sams, 2014), gamification (Kingsley & Grabner-Hagen, 2015; Rolleston, 2015; Soranastaporn, Yamchuti, & Yamchuti, 2018), and simulation of real-life situations such as virtual field trips or models can inject interest and lead to greater student engagement and motivation (Benade, 2015b; Bolstad & Buntting, 2013; Hilton & Hilton, 2013). Students can independently learn and demonstrate knowledge or skills using digital formats; exploring, achieving, competing and socialising online (Rolleston, 2015). Statements on the Ministry of Education’s enabling e-Learning website position technology as both the ‘teacher’ in terms of providing access to resources and information, and as “assisting students to be the expert”, for example, when creating their own content (Ministry of Education, n.d.-b).

Ruano-Borbalan (2006) suggests that one of the most personalised forms of education is the tutorial, where learner and tutor explore new knowledge at a pace that suits the individual learner, progressing only when the learner is ready. The role of the teacher, according to Ruano-Borbalan, is superseded in digital environments as: “In order to reach this (personalised ideal), technology must take on as much of this work as possible” (p. 89). Others suggest this assertion perhaps goes too far in that it ignores the vital relational aspect of teaching and ignores socio-constructivist views of knowledge development where learning is mediated through oral language and social interaction (Benade, 2015b; Cook-Sather, 2002).

Recent studies show that digital tools support personalised learning (Ballard & Butler, 2011; Evans, Pruett, Chang, & Nino, 2013; Song, Wong, & Looi, 2012). For example, Evans et al. (2013) demonstrated how a networked learning game can support personalised learning experiences for individual students in middle school mathematics in areas of feedback, assessment, and deep learning (as opposed to surface learning involving memorisation only). Song et al. (2012) used a mobile technology-assisted seamless learning process design to develop student agency and personalised approaches when understanding the life cycles of various living things in primary school science.

In the New Zealand science education space, Bolstad and Buntting (2013) conducted a large-scale research study into digital technologies and future-focussed science. They claim that online digital technologies can "radically transform" science learning. In addition, they maintain that "ubiquitous access" to digital resources and information means learning opportunities can be personalised to meet individual learners' needs and interests and to "leapfrog" learners into complex knowledge (p. 7). Bolstad and Buntting suggest that connections to the local and global science community mean teachers need not be the only experts (p. 23). Students could connect with scientists via Google Hangouts and/or use social media to find an expert in a particular knowledge area. With vast amounts of scientific knowledge and information available, Bolstad and Buntting argue that 'knowing what to know' becomes an issue in itself, and that curriculum and assessment decisions should work to frame reasons to find and use information (p. 20).

While many (e.g. Bergmann & Sams, 2014; Bolstad & Buntting, 2013; Järvelä, 2006; Ministry of Education, n.d.-b; Pahomov, 2014; Ruano-Borbalan, 2006) claim that the use of digital technologies offers powerful and positive opportunities for transforming teaching and learning, responses to a 2015 national survey of New Zealand secondary schools by the New Zealand Council for Educational Research (NZCER) seem to support these claims in a more muted sense. The survey found that digital technologies supported a range of learning experiences, but perhaps at a lower uptake rate than could be expected if the power and potential of digital formats are to be believed. More than 60% of teachers surveyed reported that students sometimes or often used digital devices for research using the internet, for composing, editing and formatting written assignments and assessments, for recording and sharing progress and achievements, and generating multimedia work. Less common, with fewer than

40% of teachers reporting instances, were students using digital devices to collect and analyse data, engage in distance learning, use educational games or simulations, blog, or write code and/or programs (Wylie & Bonne, 2016, p. 35). Teachers felt under pressure from expectations to capitalise on the teaching and learning opportunities offered by digital technologies and stated that they needed more time for upskilling and professional learning.

### *3.2.3 Challenges for digital technologies and pedagogies*

The use of digital platforms can present challenges for how teachers and students are able to practice. Beese (2014) suggests online courses place a great deal of responsibility on students and conclude the degree of autonomy might be overwhelming. Case study methodology was used to examine a pilot programme which offered Ohio high school students opportunities to enrol in Advanced Placement and foreign language courses through an online learning provider (p. 292). The effectiveness of online learning on student self-efficacy was evaluated, and students, teachers, and parents were surveyed to examine the challenges and barriers they encountered. While the online course overcame issues of cost associated with low student numbers and staffing allocations, high levels of teacher support were still required, and low enjoyment levels and low engagement rates led to high attrition. Conclusions were that while technology expands access to opportunities for education, a more effective model might be a hybrid which combines face-to-face teaching with online learning, so that students are supported to develop the independent technical, organisational, and time-management skills necessary for fully online formats.

Hilton and Hilton (2013) investigated the impact of digital technologies on teaching and learning in two case study contexts in Queensland, Australia. Students used video to record and represent science learning in a year nine junior class, while year 11 chemistry learning was supported using diagrammatic digital representation of molecular models (p. 154). These authors used findings from observation and student interview data to claim that the digital formats used in the case studies enhanced learning outcomes and were associated with increased motivation and engagement. In the junior class, it was interesting that the teacher was characterised as an instructor, and although confident in content knowledge, much more was involved than just teaching. Challenges arose in technological troubleshooting, classroom management, and group management (p. 157). Indications from observations were positive for student engagement, time on task, enthusiasm, collaboration, and science learning behaviours, however, questions were raised around "efficiency of practice" (p. 157), as it took time to work through teething problems. In senior chemistry learning, digital animations and simulations were promoted as helpful for assisting students' learning about abstract, invisible, and complex concepts. Careful integration of digital learning into other experiences such as traditional practical work was required. Again, time was required for teachers to become familiar with using software and finding 'bugs' before allowing student access, and more time was needed for activities to be edited by teachers. While it may be feasible to trial innovative practice in junior science, the question is whether senior classes in high stakes assessment environments would take time and energy to develop this type of approach - would it help them 'get through'?

According to Benade (2015b), pervasive use of digital technologies may have negative social effects, prioritising individualised education over the cooperative and collaborative aims of the New Zealand Curriculum (NZC). This finding could be connected to the chemistry modelling study by Hilton and Hilton (2013). Weighing advantages and disadvantages of digital learning over the customary practice of assembling molecular representations using modelling clay and toothpicks or plastic models, it can be argued that digital platforms are customisable and allow students to progress at their own pace. On the other hand, it could be argued that a practical activity using modelling clay may offer more opportunities for student collaboration, discussion, and interaction, and the physical models would also offer a concrete and tactile experience for kinaesthetic learners.

Other studies record negative effects such as distraction and off-task behaviour associated with use of digital technologies and mobile devices in secondary classrooms (Aagaard, 2015; Dobler, 2015). A study by Kay, Benzrima, and Li (2017) found that secondary school-aged students were often distracted by the use of mobile devices when engaged in independent or group work, and distracting activities included surfing the web, using social media, and playing online games. Similarly, a survey which investigated the extent to which student behaviour was a concern found that digital technologies caused issues associated with low-level distraction and unproductive student behaviours for around 50% of primary and secondary school teachers at least one or two days per week (Sullivan, Johnson, Owens, & Conway, 2014).

The issue of teachers feeling pressured by time constraints when ‘getting results matters’ was noted in a study by Lin and Bolstad (2010) which discussed the use of e-learning and virtual classrooms when moving towards 21st century pedagogies such as blended learning. The research was not subject-specific, being based around student focus-groups from e-learning clusters. Lin and Bolstad found, as Bolstad and Gilbert (2012) contend and Bisset (2014) confirms, that the availability of digital technologies and pedagogies does not result in certainty of a shift to use of those approaches. Many teachers, and even some students, found it hard to reposition themselves as 21st century digital learners. Lin and Bolstad indicated that teachers felt constrained by the need to cover the curriculum, feeling they did not have time for open-ended, collaborative Web 2.0 learning (p. 2) while students were focussed purely on ‘getting through’ NCEA assessments. A school culture prioritising academic achievement measured by “conventional assessment methods” left little room for the use of digital technologies to create opportunities for collaborative knowledge-generating practices (p. 5). As teachers in the study explained, “We’re actually teaching NCEA classes, we’re teaching kids to pass exams, and [reach] achievement standards, therefore often it’s a very intense time. You’re trying to get the information across, and there’s not a lot of time to mess around” (p. 5). The authors saw such statements as highlighting clear discord between 21st century learning ideals where digital technologies unlock new education directions, and current high stakes assessment conditions (p. 5). However, they observed that other teachers were able to make the shift to roles or positions compatible with digital pedagogues. For these teachers, the changes were made possible by seeing value for students in personalised or shared learning. Lin and Bolstad posited that students and teachers will need to “rethink their assumptions about what counts as learning” (p. 8) as well as be convinced of added value, before adopting new practice in contexts where what matters most is achievement in national qualifications.

### *3.2.4 Summary*

In sum, digital technologies offer much scope for innovative teaching and learning. Digital technologies can alter when, where, how, and with whom, teaching and learning takes place. Learning can be personalised using digital devices, with students more able to take ownership and make choices. Online learning platforms can reposition, or even replace, the role of the teacher. However, practical challenges exist. Digital tools offer distractions such as games and social media. They have been associated with off-task student behaviour. There are perceived, and real constraints associated with the use of digital technologies in high stakes assessment contexts. Constraints include the time that is required for teachers to become familiar with using software. Not all teachers see this as a priority when they are focussed on 'getting students through' NCEA assessments. In this thesis, I am interested in ways digital technologies work with curriculum, assessment, and physical space to shape the learning of senior secondary science in FLS environments.

The next section (3.3) explores the element of curriculum.

## 3.3 Curriculum

In this section, I first explain the New Zealand curriculum context in general, and secondly focus in on science as the curriculum area in which this research is based. I discuss ways in which curriculum can shape teaching and learning by offering opportunities for diverse and personalised pathways.

### *3.3.1 The New Zealand Curriculum*

The New Zealand Curriculum (NZC) positions students into their futures. The curriculum is envisioned as a 21$^{st}$ century curriculum, a "framework designed to ensure that all young New Zealanders are equipped with the knowledge, competencies, and values they will need to be successful citizens in the 21$^{st}$ century" (Ministry of Education, 2007a, p. 4). The curriculum vision includes statements of success in terms of personal growth: "young people who will be creative, energetic, and enterprising", as well as economic and environmental aims: "young people who will seize the opportunities offered by new knowledge and technologies to secure a sustainable social, cultural, economic, and environmental future for our country" (p. 8).

The New Zealand Curriculum was introduced in 2007 to replace the more prescriptive 1990s syllabi, with implementation between 2007 and 2010 (Ministry of Education, 2007b). It was designed with the "transformative intent" (Hipkins et al., 2016, p. 147) of empowering local school communities to equip students with the skills, competencies, and knowledge needed to participate and contribute in a 21st century society. Rather than tightly prescriptive of content, the English medium NZC and the Māori medium counterpart Te Marautanga o Aotearoa exist instead to set direction and provide guidance (Ministry of Education, 2007a, 2017d). The 'front end' of the NZC advances an expansive vision of developing students as "confident, connected, actively involved, lifelong learners" (Ministry of Education, 2007a, p.7). Values (such as excellence, innovation, curiosity, and sustainability), key competencies (namely thinking, relating to others, using language, symbols, and text, managing self, and participating and contributing), and the eight learning areas (English, the arts, health and physical education, learning languages, mathematics and statistics, science, social sciences, and technology) are underpinned by principles of excellence, respect for cultural diversity and acknowledgement of the Treaty of Waitangi (Ministry of Education, 2012a). These principles provide a foundation for schools' decision making when developing and implementing their local curriculum (Bolstad & Buntting, 2013; Hipkins et al., 2016; Ministry of Education, 2007a).

While the values, principles, and key competencies shape *how* students should be learning in each learning area (Gillon & Stotter, 2011), the eight learning areas themselves describe what students should "come to know and do" (Ministry of Education, 2007a, p. 37). In the NZC everyone, including the teacher, is positioned as a learner. Cross-curricular knowledge creation is encouraged (Hipkins, 2010; Ministry of Education, 2007a). Inquiry approaches are valued and encouraged as part of the Effective Pedagogy section of the NZC (Ministry of Education, 2007a, p. 34). Indeed, Gillon and Stotter (2011) argue that the NZC is "asking us, allowing us and expecting us as teachers to make inquiry learning happen in every school" (p. 14). In the NZC students are accorded the role of leaders of their learning. Teachers are to support students by challenging, giving feedback, and helping students to understand and apply their learning (Ministry of Education, 2007a). Students are expected to take ownership, and to enter into collaborative learning partnerships with their teacher and with other students (Hipkins, 2015; Ministry of Education, 2007a).

In junior school, students are expected to learn across and within all eight learning areas. In senior school, the NZC permits more choice and subject specialisation in accordance with students' future aspirations. Each school is expected to design learning programmes that provide coherent pathways of learning for students' diverse needs and interests and to support students to make pathways choices (Absolum et al., 2009; Wylie & Bonne, 2016). Science as a curriculum area offers many possibilities for diverse learning pathways, and I move now to focus the discussion on science as a learning area.

### *3.3.2 Science in the New Zealand curriculum*

The New Zealand Curriculum signals a dual intent to nurture future scientists and to develop the scientific literacy and citizenship skills of all students (Ministry of Education, 2007a, p. 17). This agenda has its echoes in the international science education literature (OECD, 2009; Rennie, 2011; Tytler, 2014). The overarching Nature of Science (NoS) strand provides the means by which students develop epistemic understandings, dispositions, and capabilities which enable them to learn how science knowledge is produced (Johnston, Hipkins, & Sheehan, 2017). The aim is to teach students to think and investigate and to participate and communicate as scientists do. Inquiry learning in science and especially more open-ended, investigatory inquiry learning experiences have been identified as important in assisting students to develop an understanding of NoS and of the complexities and uncertainties of the collaborative process of 'doing real science' as scientists might experience it (Glynn, Cowie, Otrel-Cass, & Macfarlane, 2010; Haigh, France, & Forret, 2005; Khoo & Otrel-Cass, 2017).

The disciplinary strands of Living World (biology), Planet Earth and Beyond (earth science), Physical World (physics), and the Material World (chemistry) sit beneath the NoS strand and provide the contexts within which students can develop their science skills and knowledge (Ministry of Education, 2007a, p. 28). It is expected that the NoS strand, and all disciplinary strands, are given equal attention up to year ten. After that there is considerable freedom in the NZC to design senior science programmes based around students' needs and interests.

While the science curriculum allows for specialisation at senior level in courses based on single disciplinary strands such as chemistry, biology, earth science, or physics (Ministry of Education, 2018c), it also permits other options. The field of science knowledge is vast and interrelated within science disciplines as well as other curriculum areas. For example, there is a body of international educational research related to STEM (science, technology, engineering, mathematics) subjects (Cavlazoglu & Stuessy, 2017; Kasza & Slater, 2017; Wang, 2013). Within the NZC, cross-disciplinary combinations focussing on astro-physics, marine biology, biochemistry, or biotechnology are possible. Theme-based courses such as a socio-scientific issues course which assesses learning within areas of biology and education for sustainability are also a possibility (Hipkins et al., 2016). Integrated and contextualised courses of study such as these are explicitly supported in the NZC. Advice from the senior secondary curriculum guide suggests that: "If science education is to change in response to the demands of the 21st century there must be a significant shift at the point where course design begins" (Ministry of Education, 2012b, para. 3). Teachers are encouraged to design "Flexible science programmes" and to allow for "Diverse learning pathways rather than narrow corridors of progression" (Ministry of Education, 2013, para. 3). In other words, depending on the courses that schools offer, senior students can choose to undertake science learning in the form of focussed single-discipline courses, which often specify detailed conceptual knowledges and practical skills. Or, it is possible to innovate curriculum and offer courses that are multi or cross disciplinary. In either case, the course can emphasis NoS and the process of developing scientific literacy to a greater or lesser extent. The issue in the face of so much choice and so many possibilities then becomes, what to study, and who decides?

### *3.3.3 Summary*

This section has described the New Zealand curriculum context and science in the NZC. The New Zealand Curriculum focusses on the development of knowledge and the skills and competencies needed by confident, connected, lifelong learners (Ministry of Education, 2007a). As a non-prescriptive framework, the NZC offers school communities the opportunity to design local curriculum and learning experiences to best suit their learners. While the knowledge curriculum is described through eight learning areas, learning does not need to be siloed into separate areas, as cross curricular learning is encouraged. Student-centred, inquiry-based teaching and learning is also encouraged.

In the science learning area, the overarching NoS strand aims to support students to think and learn as scientists do while the disciplinary strands focus on conceptual knowledge and understandings. There is considerable potential for innovation within the taught science curriculum in terms of flexibility in cross-curricula and cross-disciplinary learning. This freedom extends to the senior years, but at this point, high stakes assessment also exerts an influence. I next explain the NCEA (National Certificate of Educational Achievement) assessment system as the fourth and final element which impacts possibilities for teaching and learning in the New Zealand 21$^{st}$ century learning environment.

## 3.4 Assessment

This section starts with an overview of assessment in New Zealand schools. I next explain the NCEA assessment system and how NCEA supports possibilities for diverse learner pathways. I examine the intersection between curriculum and assessment in NCEA and discuss the role of NCEA as a high stakes assessment system. I review research-based studies to show that NCEA can create assessment pressures which impact the ways in which teachers and students behave. Lastly, I draw on science education literature to demonstrate that the NCEA assessment system shapes students' science learning experiences in ways which are not always aligned with 21$^{st}$ century learning ideals.

### *3.4.1 Assessment of learning in New Zealand schools*

Achievement objectives in the eight NZC learning areas provide the basis for assessment in New Zealand schools. In primary school (years one to eight), students are assessed against curriculum levels one to five. School communities can also choose to use optional assessment tools to measure and report against learning. One example at primary level is National Standards, which came into effect in 2010 and which specify expectations for achievement in reading, writing and mathematics (Ministry of Education, 2010b). Junior secondary (years nine and ten) learning is assessed against curriculum levels (four to six). Senior secondary learning (years 11 to 13, curriculum levels six to eight) is assessed at levels one to three of the National Qualifications Framework (NQF) by NCEA, which is administered by the NZQA (New Zealand Qualifications Authority). The NZC states that assessment must be "suited to purpose" and "chosen to suit the nature of the learning being assessed" (Ministry of Education, 2007a, p. 40). Values and the key competencies are not expected to be assessed in an explicit, structured way, but rather assumed to be assessed as a necessary part of purposes and outcomes of the learning areas (Haque, 2014; Hipkins, 2008). Advice is that qualitative descriptions such as examples, accounts, and narratives should provide evidence of front end skills and competencies (Ministry of Education, 2014).

Assessment of the curriculum means evaluating what students know and are able to do (Ministry of Education, 2007a) and must be considered in the context of teaching and learning, not isolated from it (Mutch, 2012). A Ministry of Education position paper places assessment at the heart of effective teaching and learning. It states that progress does not look the same for all students and asserts that the system must adjust to meet learners' diverse needs, rather than the other way around (Ministry of Education, 2010a). Students need to be able to take ownership of their learning and make 'what next' decisions. This view of assessment positions students as autonomous, competent assessors of their own learning, capable of monitoring and improving their own achievement (Cowie & Bell, 1999). Assessment capable teachers are positioned as learning experts in a transformative learning partnership (Absolum et al., 2009, Ministry of Education, 2010a).

It is the assessment of learning under NCEA that I now turn to as the high stakes assessment context for this research.

### *3.4.2 Introducing NCEA*

The introduction of the NCEA has been called "the single biggest development in fifty or so years of national examinations" (Absolum et al., 2009, p. 18). The shift to NCEA was significant as it involved a move from an examination-based qualifications system which relied on norm-referencing to a modular, standards-based system where students are assessed against specific criteria (Absolum et al., 2009; Hipkins et al., 2016). Introduced in 2002, NCEA has at times been troubled with policy, implementation, validity, and credibility issues (Cowie & Penney, 2015; Haque, 2014; Wylie & Bonne, 2016). Nonetheless, over time NCEA systems and policies have adjusted and evolved to achieve a widely accepted status as a high quality, rigorously monitored qualification with high validity and reliability of results (Hipkins et al., 2016; OECD, 2011; Wylie & Bonne, 2016).

NCEA assessments are assessments of learning (Education Review Office, 2007) which summarise and report on students' achievements for students themselves, their whānau (family or caregivers), the school, future learning providers, employers, and the Ministry of Education (Ministry of Education, 2007a; Mutch, 2012). In completing an NCEA qualification, students gain credits towards a certain certificate level by completing separate but discipline-related achievement standards. These are usually grouped together as courses or subjects such as English, science, or history. Achievement standards are typically 'worth' three or four credits. To complete level one, students must gain 80 credits across all subjects or areas of study. There are three certificate levels, with students typically completing level one in year 11, level two in year 12 and level three in year 13, although it is also the norm for students to complete credits across different levels within one year of study (Hipkins et al., 2016).

Achievement standards specify a range of internal or external assessment tasks, each consisting of detailed achievement criteria which are assessed at Excellence, Merit, Achieved, or Not Achieved. High performing students can distinguish themselves by gaining course or subject, as well as certificate, endorsement. For example, course or subject endorsement at Merit level is gained from at least 14 Merit credits. Any mix of internal or external achievement standards may be used to gain credits, however, to gain course endorsement at least one standard must be internally assessed and at least one standard must be externally assessed. A certificate can be endorsed with Merit or Excellence by achieving at least 50 credits across any courses or subjects at Merit or Excellence level (NZQA, n.d.-d; Hipkins et al., 2016).

Internal achievement standards offer teachers and students considerable autonomy in choosing tasks, contexts, and formats for assessment. Hipkins et al. (2016) describe internal achievement standards as being a "national expectation of skills and knowledge embodied in a standard, with local freedom to assess those skills and knowledge in a context that is best suited to a particular course or particular students" (p. 65). For example, in level one science, the internal chemistry-focussed investigation standard does not specify any one context but directs students to “Carry out a practical chemistry investigation, with direction” (NZQA, n.d.-e). Support in making curriculum decisions as well as for judgements of evidence of learning is available on the NZQA website in the form of exemplars, examples, and resources (NZQA, n.d.-e). Evidence of achievement in internal tasks is evaluated and moderated by teachers themselves. Random samples of student work are also selected for external moderation. External moderation of internal assessment tasks serves the dual purpose of ensuring the assessment task is suitable and reflects the requirements of the standard, as well as moderating teachers’ judgements of the evidence presented (Cowie & Penney, 2015; NZQA, n.d.-b).

External standards are usually in the form of written, externally marked examinations, although may include portfolio work in subjects with a practical component (NZQA, n.d.-b). External standards in science specify science concepts and knowledge that must be understood and applied in context. For example, the level one science chemistry external is focussed on the context of acids and bases and at Achieved level specifies that students must “demonstrate understanding” of a list of concepts such as atomic structure and neutralisation (NZQA, n.d.-e).

### *3.4.3 NCEA as an inclusive assessment system*

Achievement standards were designed to acknowledge and credential meaningful learning in a wide range of knowledge, skills, and competencies on a single recognised framework which would extend beyond students’ school learning to the workplace or to tertiary institutions (NZQA, n.d.-a). Achievement standards in dance sit at level two alongside suites of standards which make up more traditional subjects such as chemistry and history. Students can choose to gain NCEA credits in courses as diverse as Tourism or First Aid within a vocational pathway. In this sense, the NCEA has a more flexible, inclusive, pathways orientation than the examination-based system it replaced, which permitted a more restricted range of courses, and where students who did not succeed (pass examinations) did not gain a recognised qualification (Absolum et al., 2009; Wylie & Bonne, 2016).

The innovative and unfamiliar modular design challenged thinking about purposes for assessment when it was first introduced. It challenged ideas of how ‘success’ is reflected at school and who might be permitted to claim it (Haque, 2014; Wortham & Jackson, 2008). These challenges continue (Hipkins et al., 2016). While NCEA has broadened the definition of achievement, resulting in more equitable, individualized, and appropriate credentialing outcomes for *all* students, traditionally, assessment in senior school has acted as a sorting mechanism (Wylie & Bonne, 2016). A school's decile rating is a measure of the socio-economic position of a school's student community relative to other New Zealand schools, where a decile rating of ten would indicate the highest socio-economic groups and one or two the lowest (Ministry of Education, 2017c). Some (often high decile) schools decline to fully align themselves with the NCEA assessment system, choosing instead to offer dual pathways of competitive Cambridge or IB examinations alongside NCEA (Auckland Grammar School, 2015; Macleans College, 2015). On the other hand, findings from recent nationwide NZCER surveys of New Zealand secondary schools found that principals and teachers in lower-decile schools were positive about the capacity of NCEA to credential *all* students' learning gains (Wylie & Bonne, 2016). Hipkins (2015) found that in contrast to a teacher-directed approach, teachers in decile one or two secondary schools were significantly more likely to position students as active participants; involving them in setting expected outcomes for work, co-creating NCEA plans and pathways or assisting students in identifying and carrying out a personal interest project (p. 28).

In sum, the inclusive orientation of NCEA has been the cause of tensions between "traditional and more transformative expectations" (Wylie & Bonne, 2016, p. 28).

#### *3.4.4 NCEA in place of curriculum*

In principle, the NZC provides the foundation for achievement standards (Ministry of Education, 2010a). However, many achievement standards were developed before 2002 (when NCEA was introduced), from the 1990s curriculum. The 1990s curriculum consisted of a prescriptive list of topics. This has affected the way NCEA is assessed and the way teachers think about teaching and learning in terms of curriculum design (Hipkins et al., 2016; Johnston et al., 2017). Hipkins et al. (2016) suggest that teachers were "used to thinking about curriculum (in 1990s) as a list of topics that needs to be covered and assessed" (p. 148). Therefore, although the new NZC (introduced in 2007) is a non-prescriptive, framework curriculum, many achievement standards are topic based, and a course of study in senior school often becomes a list of modular standards covering topics to be assessed. This becomes an issue because under the modular NCEA system it is possible for students to engage only in learning that is relevant to any particular standard, leading to arguments that the NCEA system narrows curriculum (Locke, 2005). Some even argue the NCEA has become a 'de-facto' curriculum (Jones & Buntting, 2013; Locke, 2005). In contrast, under the previous norm-referenced examination system, students were required to learn across all curriculum topics, as any aspect of prescribed curriculum might be assessed in the final examination (NZQA, 1994).

A recent curriculum-assessment alignment process is sometimes positioned as an after-the-fact sticking plaster approach which was not fully successful in its aims of integrating "the intent of NCEA as a national qualification and intent of NZC as a national curriculum" (Haque, 2014, p. 134). Jones & Buntting (2013) suggest that in NCEA, "fragmentation into discrete internal and external subjects is both a strength and a weakness" (p. 47). As discussed above, the strength of a modular system rests in the ability to meet the needs of diverse learners with a flexible qualification which permits curriculum customisation. The weakness can be that often only that which is assessed, is taught (Locke, 2005). This can lead to a focus on assessment for credits rather than on learning within curriculum. The New Zealand Curriculum explicitly advises against over-assessment, stating that "not all aspects of the curriculum need to be formally assessed, and excessive high-stakes assessment in years 11–13 is to be avoided" (Ministry of Education, 2007a, p. 41). However, some students, rather than being curious about wider learning and curriculum contexts, instead ask: "Is it assessed?" (Hipkins & Vaughan, 2005).

### *3.4.5 NCEA assessment challenges*

This section reviews literature which highlights tensions between innovative teaching and learning ideals and the practical execution of these in the NCEA assessment context.

The flexible, modular, credit-based system has provoked contention and debate primarily due to the high stakes nature of NCEA. The NCEA is seen as a key reporting tool for accountability purposes (Absolum et al., 2009; Ministry of

Education, 2007a; Mutch, 2012) and as discussed above there is evidence of a perception that NCEA assessments, rather than curriculum objectives, drive teaching and learning in senior secondary years (Absolum et al., 2009; Cowie, Hipkins, Keown, & Boyd, 2011; Hipkins, 2013; Johnston et al., 2017). Qualifications gained in senior school are significant to individual students and their whānau as these influence pathways into employment and tertiary institutions (Ministry of Education, 2010a). Results from NCEA are also used to evaluate the success of the education system overall. In 2012, one of the Better Public Services targets released by the State Services Commission was for "85% of young people to achieve at least a level two NCEA by the time they are 18, by 2017" (New Zealand Government, March 2017).

This means that both teachers and students are under pressure to achieve. Wylie and Bonne's (2016) national survey of secondary schools found 77% of secondary teachers agreed or strongly agreed that they were under pressure to improve their students' NCEA results (p. 22). While the wider Ministry assessment strategy sets out a needs-based, student-centred vision for an ideal, responsive system, in the reality of high stakes senior assessment there is evidence that NCEA drives the curriculum, and that teachers and students prefer safe, pragmatic approaches to do what it takes to 'get through', inhibiting otherwise innovative approaches. This is in spite of flexibility and allowances within both NZC and NCEA which could be exploited (Cowie & Penney, 2015; Hipkins, 2015).

For example, these issues were emphasised in survey research of New Zealand language teachers conducted by East (2014). A new standard was developed during the standards-curriculum alignment process in the languages learning area. Named *Interact*, the internal standard was intended to replace a previous version called *Converse.* The new standard was designed to enable collection of ongoing, authentic and unrehearsed evidence of students' developing spoken language proficiency in a wide range of genuine contexts. Spontaneous interactions with other students in the class or recorded conversations with locals when on overseas trips could count as evidence for the standard. East found, however, that the supposedly spontaneous nature of the collected evidence was undermined by practices which would help students 'get through'. This led to students absurdly, painstakingly, scripting their 'genuine and unrehearsed' interactions and practicing them before they embarked on the assessment. The collection of evidence from lessons embedded in real life situations also created challenges for teacher workload and caused issues to do with assessment standardisation and reliability.

In a second example, the curriculum-assessment alignment process for the learning area of the arts resulted in a new music composition achievement standard where students are individually assessed on a collaboratively composed group performance (Thorpe, 2012). This is a complex task, and a case study conducted by Thorpe (2012) raised issues of fairness and accountability. The case study teacher noted that students who were better able to analyse and articulate their individual contributions to the composing process were more likely to achieve highly than students who were perhaps more musically talented, but less able to document their contribution. There is tension here between the valuing of students as creative contributors and the formal assessment within NCEA of that creative, contributory process. Other interesting findings in this study were that students preferred composing in a group, and that the teacher felt the approach suited the "21st century learning styles of some of her students" (p. 424).

As a third example, a study conducted by Gillon and Stotter (2012) showed that inquiry learning was less effective when compared with the power of teacher-centred approaches for 'getting students through' assessments in NCEA level one history. Inquiry in this sense meant "handing the locus of control over to the students" (p. 18) when students were learning to write essay-based answers for an external achievement standard. Students were supplied with pre-set topics and focussing questions and worked in groups to answer separate aspects of the questions before sharing their learning with the class. The authors stated that:

> Inquiry learning in the senior school is often considered problematic…we are bound by national standards which are assessed both internally and externally in a formal examination situation. The exams themselves are prescribed and fairly rigid and many teachers lack confidence and are unsure about trying an inquiry approach within the senior school. (2012, p. 14)

Gillon and Stotter claimed that the most difficult aspect of opening up senior history to inquiry approaches was trusting each group who were tasked with presenting a different aspect of the inquiry to 'deliver the goods'. With external assessments looming, "every day it seemed as if it would have been easier to shut the whole thing down and go back to the 'sage on the stage' method of teaching" (p. 18). The authors concluded overall that with carefully structured support from teachers, inquiry learning was possible and that it could successfully prepare students for formal examinations.

I now consider issues and challenges related to NCEA as the high stakes assessment context for senior science learning in Aotearoa New Zealand.

### *3.4.6 NCEA assessment challenges in science*

Science courses can be assessed at NCEA levels one, two, and three using a range of achievement standards across different science disciplines which constitute a matrix of internally and externally assessed options (NZQA, n.d.-e) (see Appendices A and B). External achievement standards in science are examination based. Internal achievement standards usually take the form of investigations involving practical or research work (Edwards, 2017).

There is evidence that assessment practices shape students' experiences of science learning and what it is to be a science learner, as well as shaping possibilities for teachers' practice (Cowie, 2013; Hipkins, 2013; Hume & Coll, 2009; Moeed, 2010). With external examinations, a key objective for teachers can be to 'get students through' knowledge-based assessments (Edwards, 2017; Spiller & Hipkins, 2013). The dominance of this focus is evident in the washback effect of NCEA into junior secondary science (Mizutani, Rubie-Davies, Hattie, & Philp, 2011). An example of this washback effect is found in a report to the New Zealand Ministry of Education by Spiller and Hipkins (2013). The report details findings of a case study which involved a single teacher and a year nine class. When teaching a unit on atomic structure, the teacher was encouraged by the researchers to think more broadly about the purposes for learning science, such the role of the Nature of Science (NoS) strand and the science for citizenship intent in the science essence statement. In spite of this, the teacher "remained resolutely focussed on successfully getting students through NCEA external examinations as her main responsibility as a science teacher" (p. 6). Spiller and

Hipkins claim that the unit set students up to complete traditional content-learning tasks, and that the assessment task was based solely on the content knowledge which year nine students would need to know for NCEA in year 11. This strategy of familiarising junior students with concepts needed at senior levels reinforces the idea that science in NCEA constitutes a body of knowledge to be consumed and remembered. Also related to the NCEA washback effect, it is widely accepted that junior students in many secondary schools commonly undergo NCEA practise exams and the NCEA grading system of Excellence, Merit, Achieved, or Not Achieved is commonly employed at junior level (Haque, 2014; Wylie & Bonne, 2016).

Hume and Coll (2010) and Moeed (2010) in separate studies criticised some NCEA level one science internal investigation achievement standards as task-focussed, with narrow questions which lead to predictable, predetermined conclusions, and which require high levels of direction from the teacher. Students in both studies were motivated simply to achieve credits and teachers appeared unable to escape the confines of planning templates and exemplar assessment schedules which dictated the type of experiments performed. In both studies the authors reported that there was a stronger focus on meeting achievement goals than on cultivating broader curriculum aims of building scientific literacy and fostering creative and critical thinking.

Similarly, recent research by Johnston et al. (2017) presents evidence that secondary science can be heavily focussed on conceptual understandings and declarative knowledge (memorisation and recall) in internal investigative achievement standards. Johnston et al. compared the representation of epistemic knowledge in NCEA in disciplines of history and biology. They argued that "students' understanding of the epistemic foundations of a discipline are likely to be predictive of their progress in that discipline" (p. 81). However, they found that epistemic knowledge was not well represented in either external or internal achievement standards for biology, despite the internal standards offering opportunity for practical, investigatory work (NZQA, n.d.-e). Johnston et al. concluded that: "Progress in biological inquiry was characterised by reduction in the level of supervision, better understanding of declarative knowledge, and of theoretical ideas, rather than by increasingly sophisticated epistemic thinking" (p. 97).

Related to this, the perception that senior secondary science entails the understanding and memorising of a predetermined set of increasingly complex disciplinary concepts may negatively impact on students' decisions to continue with science in senior school. Science may be seen as only for those more academic students who can cope (Carlone, 2012; Hipkins, 2012; Itzek-Greulich & Vollmer, 2017; Tytler, 2007). Further, there is evidence internationally that narrow understandings of science as knowledge-based can have the effect of limiting students' ability to be curious explorers in the science world (Itzek-Greulich & Vollmer, 2017). In a New Zealand-based investigation, Edwards (2017) also suggested that some preservice teachers felt senior students became too narrowly focussed on passing NCEA assessments at the expense of permitting imagination and creativity to play a part in their science learning.

The literature reviewed in this section furnishes examples of the mis-match between the intent of science in the NZC which emphasises science capabilities within the NoS strand, and what is assessed in NCEA (Haque, 2014).

### *3.4.7 Summary*

The standards-based NCEA assessment system is designed to assess a wide range of learning outcomes using a range of internal or external assessment tasks. This has resulted in more equitable, individualized and appropriate credentialing outcomes for diverse senior students. It affords students and teachers the flexibility to design a personalised curriculum. However, the inclusive orientation of NCEA has been the cause of tensions between this transformative intent and more traditional expectations of the nature and purpose of high stakes assessments in senior secondary school. Using the modular NCEA system it is possible for students to engage only in learning that is relevant to any particular standard, leading to arguments that NCEA assessments, rather than curriculum objectives, drive teaching and learning in senior secondary years. Further, there is evidence that innovation in science learning can be inhibited as teachers and students take a safe and pragmatic approach to gaining credits in NCEA. In science and especially for external examination-based achievement standards, a key objective for teachers can be to 'get students through' knowledge-based assessments. Some internal practical investigation standards have also been criticised as being knowledge-based or task-focussed, with limited opportunities for the development of epistemic understandings and creative and critical thinking.

Hipkins and Spiller (2012) argue that "curriculum creation at the NZC–NCEA intersection is already able to provide a structural framework within which '21st century' changes are made possible". However, they also concede that change is "effortful and complex" (p. 39). NCEA is sometimes even "seen as a conservative force that holds back change" (Hipkins, 2015, p. 43). This study aims to investigate ways in which NCEA assessment works as one of four elements of a learning environment to open up and/or limit possibilities for senior science teaching and learning.

## 3.5 Concluding comments

Science teacher and student identity is conceived of in this research as an observable performance, as something one *does* in terms of practice and action, rather than a more essentialist understanding of identity as something one *is.* The preceding review of literature has shown that flexible spaces, digital technologies, curriculum, and assessment each produce different possibilities for pedagogical action.

FLS are designed to facilitate personalised, student-centred approaches to learning, team teaching, and teacher collaboration, but there are challenges for teacher transition and adaptation to these new spaces. For teachers, the inhabiting of flexible spaces can be associated with feelings of uncertainty, loss of power or control, or pressure to innovate pedagogical practice. Teachers can sometimes be positioned as being at fault if they fail to make changes in their thinking and practice. Studies of digital learning have shown that it has the potential to support individual programmes of learning and to enable learning to take place anywhere, anytime, and with a range of resources and people, thus challenging the traditional role of teacher-as-expert and source of knowledge. But with new and fast-evolving digital technologies, time is required in familiarisation by teachers and students as well as time to adapt and take up these potentials. Studies of digital learning have also shown that teachers tend to resort to more familiar teaching and learning methods in high stakes assessment contexts where student achievement is important. The New Zealand Curriculum as a framework curriculum both anticipates and provides for learning programmes that can be designed to suit the diversity of needs and interests likely to be found amongst individual students. My analysis of the literature in this review has identified that the NCEA assessment system is theoretically able to accommodate an almost limitless number of learning pathways within its flexible, modular matrix of achievement standards. Yet in science and in other subject areas, it is clear that NCEA assessment, rather than the curriculum, often leads learning. A number of studies have shown that NCEA sometimes stifles innovation and holds up change when teachers and students respond to NCEA assessment as a high stakes accountability system.

Bevan-Brown et al. (2011) assert that personalised learning is essential in order to address and allow for diverse learning needs. They claim personalised learning can be the means by which the New Zealand education system responds to the challenges of the 21st century (p. 75). Bolstad and Gilbert (2012) similarly present a future-focussed vision for personalised learning pathways in senior secondary school (see section 1.5). However, looking across the four elements, it appears that in many circumstances there is tension between what is possible, and in some cases expected of teachers and learners in 21st century education environments, and how teaching and learning *actually* happens.

If principles of personalised learning are essential to allow for a diversity of learning needs and are the means by which 21st century knowledges, competencies, and dispositions are to be developed, there would seem to be a need for research which investigates possibilities and constraints for personalised learning in senior secondary science in high stakes assessment contexts.

The next chapter will review literature on personalised learning with a focus on science inquiry as a scaffold for personalisation and choice in senior secondary science.

# Chapter four: Personalised learning and science inquiry

In chapter three I argued that aspects of curriculum, assessment, physical spaces, and digital technologies provide a frame and open opportunities for personalised learning. However, there are different conceptions of personalised learning, for example, the distinctions between shallow and deeply personalised approaches which were signalled in chapter one (sections 1.1 and 1.4).

In the first part of this chapter (section 4.1), I explain the notion of deeply personalised learning. I focus on student choice as a necessary instrument in the personalisation of learning. For this I argue that different types of choice can be offered to students, and that these rely on different teacher roles when supporting students as choice-makers. The second part of this chapter (section 4.2) focusses on inquiry as a vehicle for personalising learning in science. I explain the different levels of inquiry learning which can be used to scaffold science learning and student choice. I discuss new roles for teachers and students in an inquiry curriculum, especially connected with New Zealand science education.

## 4.1 Personalised learning

### *4.1.1 What is (deeply) personalised learning?*

The idea of personalised learning is not new. For example, Cook-Sather refers to Dewey's early (1964) constructivist argument for differentiated, student-centred approaches, stating that Dewey "propos(ed) child-centred education and reject(ed) the notion that children are blank slates or empty vessels to be filled" (Cook-Sather, 2002, p. 4). Even so, reporting on a nationwide (New Zealand) online survey of educators' understandings, practices, and professional development needs relating to personalising learning, Bevan-Brown et al. (2011) suggest that many teachers' interpretation of personalising learning is somewhat limited (p. 75). There seems to be general agreement in literature reviewed for this study about what personalising learning is *not*; it does not include one-size-fits-all approaches (Benade, 2017a; Bevan-Brown et al., 2011; Dovey & Fisher, 2014; Ministry of Education, 2015c; Mackenzie et al., 2017; OECD, 2013). There is also general agreement as to the benefits for learners in terms of increased engagement and motivation in personalised learning approaches (Katz & Assor, 2007; Paludan, 2006; Patall, Cooper, & Robinson, 2008; Prain, et al., 2013).

Falk and Dierking use the term "free-choice learning" to describe "non-linear, self-directed learning" that happens informally and outside of the taught curriculum (2012, p. 1063). They suggest a need for more research into learner-centred approaches to science education that connect with individual and diverse learner motivations by meeting meets personal needs and interests. However, there is variance in the extent to which teachers believe freedom or choice in learning could or should be conferred on students themselves in the process of providing for individual needs (Paludan, 2006; Prain et al., 2013).

Some educators consider that personalised learning can be enacted within a teacher-directed curriculum using principles of differentiation. Examples of differentiation include grouping according to ability, engaging in interactive class discussions, or the provision of open-ended learning challenges (Prain et al., 2013). Other interpretations include the adaptation of curriculum and resources so that teachers present the same topic or context but at different levels of complexity or difficulty (Bevan-Brown et al., 2011). Another social interpretation of personalisation is described by Yonezawa and Jones (2007) as the organisation of the structure of a large high school so that each student is provided with strong personal support for social and academic success within a small group to which they feel they belong. Other practices associated with personalised learning include targeted, teacher-designed interventions which accommodate students with special needs, such as those who are gifted and talented or under-achievers (Prain et al., 2013). Leadbeater (2006), on the other hand, classifies a teacher-designed, differentiated curriculum as "mass customisation" (p. 111) and argues that this does not go far enough in meeting individual needs.

A different and more open-ended, yet challenging view of personalised learning is that of deep or bespoke personalisation (Leadbeater, 2005, 2006). In this view, learning can and should be customised to allow all learners to set their own targets and to follow their interests at an individual level. This view is associated with ideas of student autonomy, ownership, and choice, where students decide what, how, when, where, with whom, and at what pace they learn, (Benade, 2017a; Bevan-Brown et al., 2016; Deed et al., 2014; Entwistle, 2005; Falk & Dierking, 2012; Prain et al., 2013). Benade (2017a) proposes a meaning of personalisation as "providing opportunities for individuals to follow their interests and preferences” (p. 33). Hursh (2007) represents personalised learning not as ‘give extra help to those behind and teach them to pass the test’, but as a process of empowering students to follow individual interests and to engage with learning via their skills and passions. This view challenges implicit assumptions made by teachers and school authorities when choosing a curriculum track for all students to follow, that they know what is best for learners. It also departs from more conventional approaches to teaching and learning which are “typified by controlled use of time and space, hierarchical knowledge transmission, teacher regulation of learning routines and constraint on student agency” (Deed et al., 2014, p. 67).

Leadbeater argues that in a ‘true’ enactment or characterisation of deeply personalised learning, schools would become different places. Rather than being curriculum deliverers, he maintains that schools would become solution-assemblers. To help students access the range of virtual and face-to-face learning resources needed, schools would form networks and alliances across other schools and establishments, thereby enabling them to share resources and expertise. An individual school in a network could become a centre for excellence in a certain area while at the same time becoming a gateway to the wider shared community (Leadbeater, 2006, p. 112).

Leadbeater advises caution, however, in pushing personalised learning too far, too quickly. Leadbeater foresees challenges for deeply personalised learning in educational opportunity and equality, especially if more learning is done outside of the school setting. He warns that deeply personalised approaches may perpetuate or even increase already entrenched inequalities in achievement. As an example, Leadbeater suggests that for some students, alternative learning environments such as students’ homes may be less conducive to learning. He argues that learning at home depends upon provisions such as quiet space, access to computers and other resources, and on a parent’s ability to direct time and attention towards their child’s learning. Hence, Leadbeater proposes that a move towards deep personalisation must be accompanied by equitable resourcing at school and at home to provide opportunities for all.

Deeply personalised learning does not mean students must act alone, and neither does it de-value or exclude collaborative approaches. Working with others is a key 21st century skill and the consensus in literature is that personalised approaches can and must accommodate opportunity for meaningful relational connections and group collaboration (Leadbeater, 2005; Prain et al., 2013), especially if that is the way that individual students learn best. Moreover, deeply personalised learning does not mean that students act alone without structure or assistance. In deeply personalised environments there is a key role for the teacher in scaffolding, guiding, and supporting the process of learning and assessment (Furtak, Seidel, Iverson, & Briggs, 2012; Järvelä, 2006; Lazonder & Harmsen, 2016).

In sum, deeply personalised learning means that students are supported to design and undertake their own learning programmes relevant to their needs and interests, individually or in collaborative groups. Students who are pursuing personalised learning pathways are required to make learning choices. The next section discusses student choice.

### *4.1.2 Choice and personalised learning*

Personalised approaches are linked with increased learner interest, engagement and motivation (Flowerday & Schraw, 2000; Järvelä, 2006; Katz & Assor, 2007; Patall et al., 2008; Prain et al., 2013). According to Katz and Assor (2007), the act of offering students choices in their learning fulfils fundamental needs for autonomy, competence, and relatedness (p. 431/432). Katz and Assor argue that effective choice fulfils these needs when choice is congruent with students' family or cultural values and when aligned with students' interests and goals. Rudduck (2007) maintains that students value opportunities to make choices in their learning and to work independently on learning that is interesting to them and relevant to their everyday lives (p. 591).

There are many degrees or dimensions of learning choices. Students can be afforded choices in what they might learn within a teacher-directed curriculum area (context personalisation), or how they might undertake that learning (task choice). Using these and other forms of choice (where, when, with whom), students can be offered various levels of autonomy in their learning, depending upon the scaffolding and structure of the learning experiences selected by teachers. There are implications for teacher and student roles or identities depending on the choices that are offered and taken up.

Context personalisation (Bernacki & Walkington, 2018; Walkington & Bernacki, 2014; Walkington & Bernacki, 2018) is a form of choice that can help to make learning more relevant to students. Walkington and Bernacki (2018) claim that ownership of the context is important and that students should choose, rather than having contexts imposed upon them. These authors discuss the idea of the grain size of context personalisation. They claim that targeting a larger group for context personalisation results in increased heterogeneity and consequently, each individual involved might respond with "less precise interest in the topic" (p. 56). They propose that personalisation to smaller groups or even to individual students (i.e. fine-grained personalisation) may be particularly important for those with atypical interests. An experimental study conducted by Høgheim and Reber (2015) similarly found context personalisation and example choice increased students' perceived value of the content and triggered and maintained situational interest for middle school mathematics students. This was especially true for students with lower initial interest.

Giving students choice in pre-structured learning tasks is one concrete form of autonomy support that can be extended to students (Patall, Cooper, Wynn, & Graesser, 2010). Patall et al. (2010) conducted a large-scale, systematic experimental study that involved providing high school students with choice in pre-structured homework tasks. Findings from student questionnaires associated choice with higher levels of intrinsic motivation. Homework completion rates were enhanced, students felt more competent, and also performed better in assessments than those who did not have a choice. The authors argued that the significant positive effect on intrinsic motivation was in part due to other forms of autonomy support implied by the provision of choice, such as how well teachers listen to and understand students, or the extent to which teachers allow and answer questions. In other words, when teachers position students as choice-makers, they implicitly position them as autonomous and able, and treat them as such. However, this type of limited or supported choice between pre-structured learning tasks does not equate to deeply personalised, self-directed learning.

Different types and levels of learning choices when combined with different types of teacher scaffold and support have been shown to differentially impact student achievement and learning. Bamberger and Tal (2007) set out four levels of choice related to effectiveness of learning in museum activities. They studied 750 students from grades four to eight who participated in class visits at four science and natural history museums. At the 'no choice' level (guided, lecture-style tour), students struggled to concentrate and interactions with museum guides and teachers were often limited to behaviour management. At the 'free choice' level, students explored a whole exhibit freely with no limits on space, direction, or assignment. Teachers and guides were available to answer questions. This open choice approach was associated with fun and excitement but with less knowledge learning. The other two types of choice involved more scaffolded or structured options. In one option a discovery task was given within a restricted area of the museum and students managed their learning by choosing which peers they would work with and the order in which they would explore answers to the discovery questions. In the second scaffolded option, questions were given but students were free to choose any objects related to the questions. These limited or controlled levels of choice and autonomy were associated with high interest, discussion, engagement, and motivation as well as with meaningful learning gains. Bamberger and Tal argued that these limited choice activities acted as anchors which provided both scaffold and freedom, thereby allowing students to develop their natural curiosity into substantial learning (p. 93). This study indicates that some structure in choice could be advantageous. That is, there is a role for the teacher in scaffolding tasks and guiding students as they undertake their learning. These findings have relevance for this thesis and for the design of phase two action research which investigates possibilities for personalised science inquiry learning.

The offering of learning choices in more personalised learning environments involves the uptake of different roles or identities by teachers and students. One study from the Netherlands surveyed 253 senior students to gain an understanding of teachers' implementation of coaching roles in secondary vocational education (Ketelaar, Beijaard, den Brok, & Boshuizen, 2013). Results found noticeable differences between individuals in the extent to which teachers took on the coaching role, which was defined as facilitating personalisation and self-directed learning. Students' vocations were used as the basis for curriculum development, with students learning through authentic tasks. Attention was given to the development of students' self-regulatory and collaborative skills (p. 992). The study found that teachers remained as subject experts, but that their roles as coaches and facilitators became more significant as they guided and supported students during project work.

Granting students autonomy to make learning choices positions them as competent to do so and involves them in roles “considerably different from the types of roles that students typically perform in schools” (Mitra, 2006, p. 7). Some students may be reluctant to step outside of what they already know and understand as ‘learning’. In the context of research on student voice in pedagogical decision-making, Nelson (2014) cautions that sometimes students have been identified as a “conservative force” (p. 43) and opt for the teacher-led status quo, as this is the extent of their experience. In making the transition to personalised approaches, Shier (2006) wisely argues for a gradual transition, or as Deed et al. (2014) depicted, a gradual “loosening of the pedagogical grip” (p. 382), rather than an about-turn which students and teachers may not be ready for. As Shier observes, we can’t suddenly say to a class of young adolescents who all their lives have depended on the teacher to control their schooling: “OK kids, it’s your education, it’s up to you now to run it yourselves!” (p. 16). An interesting addition to this point is a suggestion by Claxton (2007) that for students to have the capacity to learn and ask questions they must first have a sense of belief in themselves and a sense of entitlement – that they have a right to “to ask questions, to discuss, to imagine how things could be different” (p. 119). If students are frequently positioned as followers of teacher-led learning and as receivers of knowledge or are positioned as players in a game involving instrumental strategies directed mainly at achieving required credentials, it seems likely they may find it a challenging shift to reposition themselves outside of these ways of being.

Following on from this and related to Leadbeater’s assertion that personalisation does not always offer an equitable frame for learning, is the suggestion that opportunities to personalise learning may disadvantage some students who perhaps lack the cultural or social capital to access the experiences or information that might assist them to decide upon good contexts or questions for inquiry. Some may also lack the skills and competencies needed to follow their learning through to completion (Campbell, Robinson, Neelands, Hewston, & Mazzoli, 2007). This again reinforces the idea that teachers need to offer appropriate forms of autonomy support in personalised environments (Patall et al., 2010). Teachers need to ensure that choices offered are at a level of complexity appropriate to students' age and abilities, and that learner competence to make choices is developed (Katz & Assor, 2007). It also is the teacher's duty as far as possible to ensure equity of opportunity for personalisation, even if this means teachers must actually create opportunities for some students (Yonezawa & Jones, 2007). These are important considerations for my own study where in phase two, students are positioned as choice-makers in a 21st century discourse of personalised learning.

#### *4.1.3 Summary*

Learning can be personalised using different degrees and dimensions of learning choices. The offering and uptake of learning choices involves roles and positions for teachers and students that are different from more traditional approaches, where teachers regulate learning content and control the use of time and space. In personalised environments, students can make choices about what to learn. Students can choose a context within a teacher-directed curriculum area (context personalisation). Differences in the grain size of context personalisation means that learning can be personalised at class, group, or individual level. Students can make choices about how they might learn (task choice). Presenting students with choices between a small number of pre-structured tasks is one form of autonomy support that teachers can offer. Task choice can range from more limited or controlled choices to open and less structured options.

Deep personalisation means students are able to make many choices such as what, how, when, where, and with whom, they learn. While offering choice at any level is a key influencer in student motivation and engagement, to support meaningful student learning and achievement the teacher has an important role in providing appropriate support in the form of scaffolding student autonomy and gradually developing learner competences to make and take up choices.

As science is the curriculum context for this thesis I now turn to an examination of inquiry learning which can support personalisation of learning in science.

## 4.2 Personalising learning using science inquiry

In this section I will argue and illustrate that a privileging of inquiry learning in science has been rationalised as teaching students about real science, helping students to develop science skills and competencies, and engaging students in science. I explain four different levels of science inquiry and argue that these different levels can be used to structure learning choices for students in personalised environments. I discuss roles for teachers and students working in inquiry contexts and argue for the important of teacher guidance and support in inquiry learning. I also note challenges for inquiry learning in science, especially those associated with NCEA assessment contexts.

### *4.2.1 What is science inquiry?*

Within the science education literature there is evidence of variance in teachers' understandings and beliefs about what is involved in science inquiry (Bevins & Price, 2016; Blanchard et al., 2010; Crawford, 2007; Haug, 2014). Science inquiries can be viewed as predictable confirmation activities or as open opportunities to explore the world, allowing students to take the lead, and 'be' scientists (Anderson, 2002; Capps & Crawford, 2013; Haigh et al., 2005; Prince & Felder, 2006). In general, science inquiry learning involves supporting students to ask and investigate questions, design methods, collect and interpret data, and form evidence-based conclusions (Bevins & Price, 2016; Blanchard et al., 2010; Capps & Crawford, 2013; Chen & Tytler, 2017; Crawford, 2007; van Rens, Pilot, & van der Schee, 2010). Inquiry learning has been shown to increase student motivation and to engage students in science who might otherwise be turned away (Bevins & Price, 2016; Furtak et al., 2012; Minner, Levy, & Century, 2010).

Tytler (2007) argues that a reimagined science education for the future should include science inquiry as an important approach that emphasises exploration and questioning. In Tytler's view, investigations as inquiries should flow from students' questions and allow students to learn how scientific knowledge is developed. Inquiry learning should allow students to experience working scientifically in activities such as gathering data and using evidence to make claims. He contrasts this inquiry approach with more conventional school science, which he claims is "designed principally to train young people as a preparation for entering the science discipline, (and) is the very instrument that is turning (students) away from science" (2007, p. 15). Tytler argues that conventional transmissive pedagogies which focus on concept acquisition are often relied on but are not compatible with involving students in active science learning or with conferring on students a sense of control in their learning. Further, Tytler rightly contends that science curriculum design and assessment systems need to be reimagined to support and respond to inquiry learning ideals.

Berland et al. (2016) similarly suggest that an emphasis on science inquiry can shift the focus from learning about science to doing science and to involving students in the work of "knowledge construction and evaluation" (p. 1082). Ruiz-Primo, Tsai, and Schneider (2010) discuss scientific inquiry as an epistemic goal which can be used to engage middle-school students in the processes of scientific knowledge development. They argue that: "Scientific inquiry is fundamentally about collecting data, transforming those data into evidence, and that evidence into explanations" (p. 605). Likewise, Capps and Crawford (2013) propose that through inquiry students gain a deeper understanding of epistemic knowledge or the nature of science as a process, including how scientists work and how science as a knowledge field has developed. Chen and Tytler (2017) note that although inquiry learning involves the active involvement of students in reasoning and exploring ideas, teacher guidance is still important. The teacher needs to be actively involved in "monitoring, shaping and responding to students' ideas" (p. 95) in a way that is appropriate to the goals of the activity and the age and experience of the students. A meta-analysis of the effects of guidance in inquiry-based learning by Lazonder and Harmsen (2016) came to similar conclusions. They found that students learn more in terms of skills and domain knowledge in inquiry than explicit instruction, but only if students receive adequate, level-appropriate guidance during the inquiry.

Mallya, Mensah, Contento, Koch, and Barton (2012) argue that an inquiry context which has been carefully chosen by the teacher can extend and challenge students' learning. Their study attempted to extend science learning beyond "traditional, content-focussed curricula which prepares students for the 'science pipeline'" of science related careers (p. 244). They sought to create meaningful learning opportunities which connected school science to issues of personal and social significance in students' lives. Data was collected from eight seventh grade case study students who were involved in semi-structured interviews. As well, artefacts such as student work and activity sheets were collected, and classroom observations conducted. Findings included that students used their understandings of school science in the teacher-supplied context of health, nutrition, and exercise to support their decision making in their own food choices (p. 265).

The approach described in Mallya et al.'s study is common in literature – the teacher chooses one (supposedly) engaging context for the class to study (Fusco & Calabrese Barton, 2001; Kanter & Konstantopoulos, 2010; Rahm, 2002). However, as Walkington and Bernacki (2018) point out, targeting a larger group for context personalisation may not result in increased interest for all students in the group. Olitsky (2005) designed force problems for a physical science class using the context of football and the Philadelphia Eagle football players. Olitsky noted that teachers' efforts to attach science tasks to contexts that they perceive to be important in students' cultural and social worlds may not be appreciated by students and are often not sufficient to generate sustained interest. Connecting to Olitsky's study, Seiler (2013) also cautioned that "teachers and curriculum developers often do not do a very good job of picking topics that students see as relevant to their lives" (p. 368) and that students do not always share the teacher's enthusiasm for a carefully chosen topic. Seiler quoted one student who candidly remarked: "I mean, you can't think that just cause you think it's fun, we gonna think it's fun" (p. 369). Instead, Seiler's investigation of student choice and voice in science curricula found that "when science questions, topics, and examples emerge from the students themselves, they can foster promising patterns of student engagement" (p. 368). Furthermore, it was found that students who were not usually expected to be successful in science were able to connect science to their own experiences, for example, from watching movies and television, in ways that were "nothing short of amazing" (p. 368). The different perspectives and findings involving teacher-chosen contexts or student-led choice in inquiries discussed in the paragraphs above need to be taken into consideration when planning learning choices and personalised science inquiries.

Blanchard et al. (2010) provide helpful descriptors for distinguishing between different instructional approaches to types of science inquiry (p. 581). Four levels of science inquiry (verification, structured, guided, and open) are defined below.

At the first level of inquiry, Blanchard et al. note that verification methods involve high levels of teacher control and teacher direction. Options for personalised approaches are limited as the source of the question and methods of data collection are pre-set by the teacher at class level. In practical investigations, verification-type inquiries are those where students follow explicit laboratory procedures using cookbook methods, and findings are confirmed by the teacher. Osborne (2014) is critical of verification-type practical investigations because, in his view, they confuse the goals of (school) science. In Osborne's view, *doing* science or hypothesising, experimenting, and evaluating evidence to discover new knowledge about the material world is confused with the goal of *learning* science as a process of building an understanding of the natural and living world that surrounds us (p. 178). Osborne concludes that verification-type investigations merely serve "the pedagogic function of illustrating or verifying the phenomenological account of nature offered by the teacher" (p. 178).

At the second level, structured science inquiries involve teachers providing the task and methods for collecting data (Blanchard et al., 2010). Students are responsible for carrying out data collection and for interpreting results. Guided inquiries, on the other hand, present more opportunity for student autonomy and choice. At this third level, students are required to decide on methods of investigation for a teacher-supplied question before collecting data and interpreting results. A large-scale comparison study of American middle and high school students by Blanchard et al. which examined the efficacy of guided inquiry compared with traditional verification methods found guided inquiry to be effective in supporting students' achievement (p. 589). Lastly, at the level of open inquiry, the source and design of the question, the data collection methods, and interpretation of results are all open to the student (Blanchard et al., 2010). These descriptors of four levels of inquiry will be used to refer to various types of inquiry learning conducted in this study in phase two action research.

Looking across the different levels of inquiry, open inquiry could seem to offer the greatest potential for deeply personalised science learning (Leadbeater, 2006). However, Blanchard et al. caution that open inquiry must not be conflated with minimally guided approaches such as discovery learning or problem-based learning. In accordance with others, such as Chen and Tytler (2017), they stress that the teacher still must provide guidance and support. Students cannot be left to discover knowledge on their own, with no teacher intervention. Blanchard et al. argue that the optimal level of support will vary according to the prior knowledge and inquiry experience of students, the classroom context, and curriculum demands.

Teachers can offer students various types of support at different stages in open inquiries. Roth (1995) and Yerrick (2000) suggest that teachers who are competent in specific scientific disciplines can support students in the process of framing their initial wonderings into research problems within the disciplines, and that even students who are typically less academically successful are capable of asking and constructing their own research questions for inquiry. Adler, Schwartz, Madjar, and Zion (2018) note that in open inquiry learning, one form of autonomy support that teachers can extend to students is acknowledging their ownership of the inquiry by respecting their questions and enabling students to make their own choices when conducting the inquiry. Adler et al. (2018) also stress the central role of the teacher as motivator and providing practical support for process management and challenges that students may encounter.

In sum, science-as-inquiry can assist students to gain a deeper understanding of the nature of science as a process, how scientists work, and how science as a knowledge field has developed. It is possible to structure science inquiries using different levels: verification, structured, guided, and open. Each level involves different types of student input into the various aspects of the inquiry process. Within the different levels, the nature of teacher scaffolding and support varies. There is a high level of teacher direction and involvement at every stage in verification-type inquiries. In open inquiries, while still under the teacher's guidance, students are supported to decide upon their own questions. Students are also supported to design their own methods of investigation, and to collect, evaluate, and report on their findings (Blanchard et al., 2010). This kind of inquiry offers the most possibilities for personalisation.

### *4.2.2 Science inquiry learning: New roles for teachers and students*

Science inquiry learning has implications for teacher and student roles (Anderson, 2002; Bevins & Price, 2016; Chen & Tytler, 2017; Crawford, 2000; Furtak et al., 2012; Minner, Levy, & Century, 2010). Significantly, Crawford (2000) suggests that inquiry-based instruction requires the teacher to perform a broader range of roles that require a higher level of teacher involvement than either traditional teacher instruction or less guided, discovery learning. Crawford conducted an in-depth case study of an experienced high school biology teacher to explore ways in which he engaged his students in self-directed science inquiry learning. Roles for teachers were identified as being more demanding and complex than the usual descriptors of facilitator or guide. For example, the role of collaborator involved students and teacher exchanging ideas and delegating some aspects of his teacher role to students (p. 932).

Teachers can find the shift towards more student-led roles in inquiry to be challenging. Sharples et al. (2015) reported on the design of an online scripted system to support personal inquiry in science for students aged 11-14 years. Inquiry methods were found by teachers to be time-consuming, hard to manage, and "at odds" (p. 310) with the way that science learning is normally delivered. Danielsson and Warwick (2016) argue that teachers' conceptions of science learning are influenced by their own experiences of learning science and that this may contribute to difficulties in embracing the idea of science as inquiry. They point out that many teachers have experienced science as the "presentation of a set of disembodied facts to be learned" (p. 290) and an "experience of practical science as a set of 'safe' activities with predetermined outcomes" (p. 299). Danielsson and Warwick further note that challenges associated with embracing an inquiry approach can be linked with insecurity due to teachers' perceived lack of wider science knowledge.

This was true for a teacher of physics in a case study conducted by Levinsson, Hallström, and Claesson (2013). The teacher was asked to formulate an action plan based on aspects of formative assessment which he found particularly interesting. The physics teacher chose to trial a "conversation-based teaching" approach (p. 131), allowing different student perceptions of and interests in topics to be expressed. As such, this was perhaps more a student-led learning approach than inquiry learning. Even as the teacher recognised the value of trialling new practice, the uncertainty associated with moving away from teacher-centred transmission styles was apparent. The teacher was worried that his lack of depth of content knowledge might be exposed and was reluctant to risk "revealing his inabilities to handle his new role in front of the students" (p. 133). His concerns were amplified by the tensions between meeting individual learning needs and getting through the curriculum under time pressure. There was also evidence of students' resistance. Students merely wanted to get the right answer and to know their grade. Student resistance to change in this study reinforces Nelson's (2014) claim above that students themselves can sometimes act as a conservative force in the face of change. The most significant change for the physics teacher was that he now felt he put students' learning first as he overcame issues and became conversant with his new role (p. 134). Levinsson et al. acknowledged the limitations of focussing on a single teacher, as the barriers reported might have been unique to the one individual. Nevertheless, they reasoned other teachers may experience parallel struggles and identify with some of the conclusions.

Similar issues were cited by Williams et al. (2013) who investigated the practicalities of using e-networked tools in science inquiry. They sought to find out how the use of such tools might offer new and different ways for diverse students to engage with, explore, and communicate science ideas in a science inquiry context. Case studies were conducted in three New Zealand high schools with six teachers who had varying knowledges and experiences of inquiry learning and using e-networked tools (p. 13). The classes in which the studies were undertaken were at junior level (years nine and ten), therefore the fit of inquiry learning for NCEA assessment was not a consideration. Even so, the report contained conclusions pertinent to this review. Findings were that to support e-learning inquiry, the infrastructure must be both available and function as intended, and flexibility in both curriculum and assessment processes are necessary. E-networked tools facilitated authentic learning where students were engaged, able to take ownership, and focus on an area of interest. Teachers needed time and support to implement new approaches, and to develop the confidence to interact with students and share information while working with knowledge possibly unfamiliar to them. Teachers spoke of having to "let go of the learning" (p. 14) and "take a secondary role" (p. 15), reflecting a perceived change in position. For students in the study, inquiry meant active learning in the form of choosing, refining, and investigating questions, and required both more collaboration and more independence, along with development of competencies such as being self-managed and self-directed. They needed to be taught the skills of inquiry and scaffolded into their independent learning roles. Students also needed to adopt new ways of learning as they came to rely on sources of knowledge other than their teacher.

### *4.2.3 Science inquiry in the context of NCEA*

Internal NCEA science investigation achievement standards are structured at different levels to provide varying degrees of openness and inquiry support. At NCEA level one students undertake investigations similar to Blanchard et al.'s classification of structured inquiries. Level one achievement standards specify that teachers must provide "direction" (Ministry of Education, n.d.-a). However, Hume and Coll (2009, 2010) and Moeed (2010) from different theoretical positions concluded that level one science investigations were often enacted as verification type activities, with students undertaking trivial investigations with predictable outcomes, where if experiments failed to go to plan, students fabricated results (see section 3.4.6).

At NCEA level two students are to be given "supervision" (Ministry of Education, n.d.-a). Contexts or questions for internal investigation standards can be supplied by the teacher or chosen by the student. Students then plan and carry out the investigation, interpret and discuss results, and write conclusions. This approach can therefore be equated to Blanchard et al.'s guided or open inquiries. For example, the level two earth and space science practical investigation teacher guidelines state that "the context of the practical investigation may be chosen by the teacher and/or the students" (Ministry of Education, n.d.-a). At NCEA level three, students must show even more independence and teachers may provide only "guidance" (Ministry of Education, n.d.-a). This wording requires students to formulate and investigate their own questions, leading to a more open, albeit teacher-supported, inquiry.

Returning to Tytler's (2007) assertion that science curriculum and assessment systems need to support and respond to inquiry learning ideals, there is opportunity for supported inquiries and for genuinely open-ended inquiries in some internal NCEA achievement standards at levels two and three. Therefore, there is opportunity for science learning to be more personalised at senior secondary level.

### *4.2.4 Summary*

Different inquiry approaches involve different types and levels of openness and student choice. Open inquiries involve high levels of student autonomy and choice and this can be contrasted with teacher-directed verification inquiries. In structured inquiries the teacher provides the task or questions, and methods of gathering data. In guided inquiries the teacher directs the questions for learning while students decide on a method for investigation. Each level of inquiry requires teacher guidance and support. The more open the inquiry, the more teachers' roles shift towards autonomy support and scaffolding, while students' roles shift towards more independence and choice. Teachers can offer various forms of autonomy support in open inquiries. This can include helping students to structure questions for their inquiry, providing practical process support, and acting as a motivating influence. Internal NCEA science investigation achievement standards provide possibilities for personalisation of learning in open, student-led science inquiry, especially at levels two and three.

## 4.3 Overall conclusions: Literature review chapters three and four

Chapter three established a framework for examining how the discourse of 21st century learning might play out within secondary science classrooms. The framework consisted of four separate yet interconnected elements of a learning environment: curriculum, assessment, flexible learning spaces, and digital technologies. The possibilities and challenges within these which impact what teachers and students can do were set out. Chapter four discussed opportunities and challenges associated with personalised learning and the potential of inquiry learning approaches in the pursuit of personalised science learning. In open inquiries and in personalised learning contexts, students are able to make choices about what, where, when, how, and with whom to learn. Within inquiry approaches the teacher's role is to support students so that they are competent to make choices according to their needs and interests, and to ensure structure and scaffolds are in place so that students are able to proceed and achieve as autonomous learners.

Circling back to the Bolstad and Gilbert report précised in the chapter one, while ideas of "changing the scripts" (2012, p. 39) about teaching and learning in 21st century contexts are well established, in practice, science teachers and students must first be able to 'take on' new roles and identities associated with these shifts. What *does*, and what *could,* senior secondary science learning look like in Aotearoa New Zealand? To date, little research has been conducted in New Zealand NCEA senior science learning environments with a focus on if and how opportunities for personalised learning can be created, conceptualised, and enacted. It is hoped that this study will contribute to understanding of issues and opportunities associated with personalised science inquiry learning and assessment at senior levels.

In the next chapter I outline proposed steps to discovery in terms of rationale for research design, data generation methods, and analysis of data for both phases of research. I explain how the chosen research methods fit within a constructionist theoretical framework. Key ethical considerations and strategies for establishing legitimacy are also discussed.

# Chapter five: Research methodology and methods

In chapter one I introduced the idea of 21$^{st}$ century learning as a discourse. In chapter two I introduced and explained aspects of social constructionist theory within an interpretive paradigm as both a philosophical framework and as a methodology (Fereday & Muir-Cochrane, 2006). I argued that different schooling discourses produce different meanings and versions of teaching and learning, and that science teacher and student identities are enacted as people are positioned in relation to these. In chapter three I examined ways in which the discourse of 21$^{st}$ century learning is represented in a framework of four elements of curriculum, assessment, physical spaces and digital technologies. I argued that underpinning the discourse of 21$^{st}$ century learning is a commitment to, and expectation for, personalised or self-directed learning approaches, and in chapter four I investigated the idea of personalising science learning using inquiry. However, I also questioned the idea that the discourse of 21$^{st}$ century learning necessarily translates to a different reality in terms of teacher and student practices and identities at the coalface of classroom life. I argued further that the powerful traditional science schooling discourse which is sustained by existing policies and practices can be in tension with alternative 21$^{st}$ century practices and meanings.

The overall aim of this research was to use constructionist theory and thinking tools to consider ways in which the discourse of 21$^{st}$ century learning might influence senior secondary science to reposition teachers and students of science. The following overarching research question guided the study:

> *How might the discourse of 21$^{st}$ century learning influence notions of senior secondary science to offer different identity descriptions for science teachers and learners in Aotearoa New Zealand?*

The research was designed in two phases to explore this question. The first phase inquired into what 21$^{st}$ century senior science learning *looks like* in 21$^{st}$ century learning environments in the 'now', while the second phase was designed to investigate what senior secondary science learning *could* look like as personalised inquiry.

These phases were guided by the following sub-questions:

Phase one sub-question:

> *What does science teaching and learning look like in flexible learning space schools, when teachers and students are focussed on NCEA science assessment?*

Phase two sub-question:

> *What could science teaching and learning look like in flexible learning space schools, when teachers and students are focussed on NCEA science assessment?*

This chapter explains the design of this research in methodological and practical terms. The first section outlines research approaches for phase one (section 5.1). It describes how I joined with teachers and students in three New Zealand secondary schools to undertake the research and explains processes of data generation. Section 5.2 details approaches to phase one analysis. Sections 5.3 and 5.4 outline and explain research approaches and analysis for phase two. Lastly, in this chapter I explain techniques used to establish quality in this research and discuss considerations and actions important in ensuring ethical practice (section 5.5).

## 5.1. Phase one research methods

### *5.1.1 Case studies*

The overarching research question asks how the discourse of 21st century learning is shaping notions of senior science education and enquires into the impact of this on science teacher and student identities. The phase one research sub-question is an exploratory question which asks what science learning *actually* looks like in 21st century environments. The focus is on specific elements of physical space (FLS), digital technologies, science in the New Zealand Curriculum (NZC), and assessment (science in NCEA). The sub-question invites a richly textured answer in the form of a situated, descriptive portrayal of a learning environment and of the structural, institutional, and social complexities within (Ezzy, 2002). The research approach needed to allow for the collection of diverse data from multiple sources (Maeng & Bell, 2015; Merriam, 2014) at both the macro or structural, and micro or interactional level (Burr, 2003).

Case study was chosen as the research approach in phase one. Case study research allows the researcher to explore real-life situations in depth and accommodates the complexity of human interactions (Cohen et al., 2011; Maeng & Bell, 2015; Yin, 2014). The focus is on insight, discovery, and interpretation (Merriam, 2014). Case study research does not place limits on the types of data that may be gathered or on subsequent theoretical approaches to analysis (Yin, 2014). In fact, Yin (2014) argues that case studies benefit from "theoretical propositions which guide data collection and analysis" (p. 17). In this research, social constructionist theory offers a different way of seeing and interpreting the structural, institutional, and social complexities in science learning environments.

Case studies employing qualitative data collection methods do not yield statistically generalisable, representative samples (Cohen et al., 2011; Hamilton et al., 2013). Yin (2014) suggests instead that in case study research it is possible to strive for analytic generalizations. Analytic generalisations are those which highlight issues that others might encounter or insights which could have application in other settings. At best, a case study should be presented in such a way as to allow readers to judge the implications of the study for themselves (Cohen et al., 2011; Hamilton et al., 2013).

Using a multi-case study design (Yin, 2014), three different secondary schools were approached to participate in this study. This was to enable a broader picture to emerge from insights across a range of science learning environments. Each contextually diverse environment was studied as a bounded system (Yin, 2014). The case studies were intended to show teachers and students positioned variously by different affordances and constraints and examine how identities were being constructed.

### *5.1.2 Portraiture*

In addition to developing individual school case studies when exploring what science learning *looked like*, I wanted to illustrate in a holistic way what *might* be possible if practices and features from each case study were combined. I decided to produce a synthesis of key features from across the cases and to present this as an illustrative session, detailing in narrative form the science teaching and learning activities that might take over a 90-minute session.

To achieve this, I employed a variation on the technique of portraiture. Portraiture is a particular kind of narrative inquiry which was pioneered by Sara Lawrence-Lightfoot (1983). In developing the technique, Lawrence-Lightfoot set out to portray the stories of six American high schools as “life drawings”, capturing the character and culture of each and illustrating “the mix of ingredients that made them good schools” (Lawrence-Lightfoot, 2005, p. 5). Portraiture is a creative endeavour that requires attention to both “empirical description and aesthetic expression” (Lawrence-Lightfoot, 2005, p. 10). Portraiture is distinguished from other qualitative methods for documenting and presenting findings by its affirmation of creativity and aesthetics and by its treatment of researcher voice as integral to the production and composition of a portrait (see also Chapman, 2005; Lawrence-Lightfoot & Hoffman Davis, 1997; Quigley, Trauth-Nare, & Beeman-Cadwallader, 2013). The researcher as portraitist actively imposes a story on the data by selecting themes and subplots as well as by “defining the sequence and rhythm of the narrative” (Lawrence-Lightfoot, 2005, p. 11).

Portraiture is analogous to an artist painstakingly producing a painting, capturing a likeness by paying attention to detail (Lawrence-Lightfoot, 2005; Lawrence-Lightfoot & Hoffman Davis, 1997). The researcher as artist is a witness; interpreting and demonstrating the complexities of context, characters, and culture (Chapman, 2005, Lawrence-Lightfoot, 2005; Quigley et al., 2013). A portrait is constructed from many brush strokes which compose the whole, in other words, ‘subjectifying’ the object of interest through the author’s eyes. Thus, a portrait is more than a photograph or snapshot which treats the subject in a one-dimensional or superficial manner (Chapman, 2005). The concept of analytic generalisation applies (Lawrence-Lightfoot, 2005). That is, the subtlety and detail of close and specific descriptions in portraiture aim to illuminate for a reader an issue or theme. Key to the technique is a focus on highlighting success while recognising that due to the complexities and dynamics of social systems, failures and imperfections are always present, and that there is something to be learned from both (Hackmann, 2002; Lawrence-Lightfoot, 2005).

Portraiture can be used in conjunction with different theoretical frameworks to explore and illustrate complexities in issues or phenomena (Lawrence-Lightfoot & Hoffman Davis, 1997; Quigley et al., 2013). Chapman (2005) offers an account of the way critical race theory and portraiture can be combined to acknowledge the author's role in meaning-making and the expression of participants' voices in a case study of a white teacher in a racially diverse classroom. Similarly, Lynn (2006) used portraiture with critical race theory to tell the story of a young male African-American teacher in an urban middle school. In employing this combination, Lynn connected with the teacher's voice in descriptions of ways race and gender interacted in the teacher's life, while interspersing these with his own impressions, descriptions and interpretations. The final product was a portrait of the teacher's "dance between two worlds" (p. 227); the world of the streets and community where he grew up, and the world of school-teaching and academia.

Hackmann (2002) suggests portraiture provides a viable methodology for thinking about educational change and as a way of presenting and applying knowledge to solve real problems. According to Quigley et al. (2013), portraiture is under-utilised in education and little used in science education research. The authors presented portraits of two female science teachers which explored and illustrated how different school contexts influenced teachers' experiences of science teaching and their classroom pedagogies. They argued for the viability of portraiture as a qualitative methodology for science education research which supports rich, thick descriptions of context and representation of participants' voices.

In this research, a portrait is presented as a cross-case study of what science learning *might* look like. The portrait draws together themes from phase one and in this sense is a step to action for phase two (Cohen et al., 2011; Hamilton, Corbett-Whittier, Lagrange, Birch, & Scott, 2013).

### *5.1.3 Identifying and joining with participants in Phase one*

A purposive or criterion sampling approach was used to identify possible phase one schools. This approach involves cases being selected on the basis of their fit for the research due to the possession of particular characteristics (Cohen et al., 2011; Moeed, 2010; Yin, 2014). To keep travel times manageable, I was looking for secondary schools within a 90-minute drive from my research base, whose science learning spaces fitted into the category of flexible learning spaces as defined in section 1.3. Most New Zealand secondary schools were built as cellular classroom blocks prior to the year 2000 (Bisset, 2014), with the transition to flexible spaces ongoing from then during property upgrades or as new schools were built. Within my research area I found five secondary schools which fitted the criteria of having flexible science learning spaces. That is, having an architecture of open, shared spaces, smaller breakout areas, moveable, transparent walls and mobile furniture, as well as integrated wired and wireless technologies to support digital learning.

The first step in joining with participants in phase one was to visit the principals of these five schools to discuss the research. In most cases during these first visits I was taken on a very informative tour of the school. During these tours I talked with principals about their school’s learning philosophies and asked questions about the design of learning spaces. These initial visits and discussions were vital to me in inspiring further wonderings and for informing directions for the research. All five principals were supplied with information letters and research consent forms (Appendix C) and all agreed to be part of the study, however, keeping in mind travel times and the volume of data that would ensure analysis was manageable, I chose three of the five schools as research sites.

I then contacted the science curriculum leader at the chosen schools and arranged a meeting at which I explained the research and invited them to participate. The next step was to invite teachers of NCEA science classes to participate (Appendix D). In school one and school two I was fortunate that two teachers who shared responsibility for a large group of level one science students volunteered to participate. The third school had a small roll and I was thankful to be granted access by the single teacher of level one science. In total over the three schools, five teachers and three science curriculum leaders participated in the research by allowing me to interview them and by permitting me to observe their classes in action.

Before I commenced classroom observations and student interviews I talked to students in the science classes. I explained who I was, what the research was about, and invited students to participate (Appendix E). Year 11 (NCEA level one) students were mostly 15 years and younger. Therefore, I distributed information and consent letters to be taken home for parents to sign (Appendix F).

### *5.1.4 Instruments for data generation in Phase one*

The main methods of data generation used in phase one were participant observation and interviews. I first discuss participant observation and interview in general.

**Participant observation in Phase one**

Observational research is employed to capture key moments and happenings by gathering live data from naturally occurring events (Cohen et al., 2011; Denzin & Lincoln, 2013; Hamo & Blum-Kulka, 2004; Mason, 2002). The implication is perhaps that an observed reality can be accurately translated to an actual 'true' representation. In constructionist understandings of observation, however, it is recognised that there is no single, observable, reality which can be interpreted as 'the truth' about any one situation. Each different reality is framed by a different observer (Burr, 2003, 2015). Denzin and Lincoln (2013) similarly describe the influence of the observer and imply the existence of multiple realities when they suggest:

> There is no clear window into the inner life of an individual. Any gaze is always filtered through lenses of language, gender, social class, race, and ethnicity. No objective observations, only observations socially situated in the worlds of-and between-the observer and the observed. (p. 24)

Likewise, it is recognised that it is impossible to record everything about any situation. According to Mason (2002), observational research is a form of focussed noticing, and descriptions are interpretations which produce one possible picture or representation from a multitude of choices and possibilities.

In each of the three case study schools I formally observed two 90-minute sessions, although as I came and went in the process of conducting teacher interviews I observed other aspects of classroom life over a longer period. All interviews and participant observations in all three schools were conducted in term three, from July to September 2016.

As a participant observer I was active in moving and mingling during science sessions, capturing data 'in the moment' as well as stepping back to observe and reflect in a more detached manner (Hamo & Blum-Kulka, 2004; Merriam, 2001;

Mutch, 2005; Spradley, 1980). Voice recorded data included recordings of unstructured classroom talk in the form of natural speech and conversations (Mori & Zuengler, 2008). Audio voice recordings captured language details such as how students talked about their work, ways teachers led the learning, how learning was introduced, and the nature of teacher-student and student-student interactions. I also audio-recorded talk *about* being a teacher or student in the form of unstructured interviews. I carried a small digital voice recorder with me at all times. This could be quickly turned on and was effective in capturing speakers' voices from near and far away while minimising ambient noises. For example, the recorder would pick up the teacher speaking to the whole class even if I was on the opposite side of the space.

I also carried an iPhone 7 on which I could take quality photographs of learning spaces, student work, and of students and teachers interacting during lessons. I also used the iPhone to record video. However, I found video recording to be intrusive and was very cautious in my use of this, only collecting short clips and often giving an audible commentary so those participants near me could understand what I was focussing on as I panned the room. During the lessons I took field notes to complement the voice recorded and photo/video data. These notes recorded aspects such as activities taking place, physical movement and positioning of teacher and students in the space, interactions between teachers and students, and the use of resources and digital technologies. I often found it easier to use the voice recorder to capture my thoughts and reflections. I would find a quiet space and speak thoughts directly into it during class time. I would openly describe happenings within participants' hearing, and would reflect into it immediately after class, while walking out of school and on the drive home.

Other documentary data collected included NCEA assessment information provided by the teachers, worksheets given to students, student work samples and student achievement results.

**Interviews in Phase one**

A qualitative research interview attempts to understand participants' lived experiences of the research context through an exchange of views in purposeful conversation (Brinkman & Kvale, 2015; Cohen et al., 2011). A constructionist conception of the research interview sees knowledge generation as a co-

construction between researcher and participant/s who are each situated in uniquely individual cultural, social, and historical contexts (Koro-Ljungberg, 2008). Brinkman and Kvale (2015) similarly describe the interview process as the social construction of knowledge. They refer to interview participants as *subjects* to indicate that they are subject to, or positioned by, the discourses, power relations, and ideologies in which they are immersed, and which work to constitute what they may talk about and how. In constructionist thought, the researcher's own assumptions (arising from their own discursive located-ness) are understood to inform the questions asked, which in turn offer implied positions from which the interviewee is able to answer (Burr, 2003; Harré & van Langenhøve, 1999).

Recognising the implications of constructionist conceptions of research interviews, I sought as far as possible to ensure interviews were dialogic in nature and that questions invited multiple viewpoints, with no (intentional) restriction or position implied (Brinkman & Kvale, 2015). I also remained conscious of the effect of inviting certain issues into the conversation. For example, from previous experiences of conducting focus groups with secondary teachers about NCEA, I knew that NCEA had the potential to be a contentious topic, and that once a conversation became focussed on a problem narrative (Kecskemeti, 2011), it could be difficult to move on from it. Therefore, I was always careful during interviews to frame my questions in a way that positioned NCEA as neither a problem nor an advantage. When interviewing students, I was aware that they might sometimes give the answer they thought I would want to hear. I was also aware that I could very easily generate a certain type of answer by offering students certain positions from which to speak (Drewery, 2005), hence again I was careful in my framing of questions (Brinkman & Kvale, 2015).

In this research, unstructured interviews during participant observation of science sessions and more formal, semi-structured interview techniques were employed to generate language data as teachers and students talked about teaching and learning in senior science. Semi-structured interviews were conducted with the five teachers and three science curriculum leaders in the study. These interviews lasted around 60 minutes. They were exploratory interviews seeking to hear experiences and perceptions of being teachers of NCEA science in FLS spaces. Post my classroom observations and once I had transcribed and analysed the first interviews, a second interview (30-60 minutes) served as a participant validation process to ensure my initial analysis of observations reflected participants' perceptions and experiences (Corwin & Clemens, 2012, Kornbluh, 2015; Maeng & Bell, 2015).

Each teacher interview followed a similar pattern. In the first interview I began with an open question such as: "If you think about working with a level one science class - what does teaching and learning look like?" I intended for participants to take this in whichever direction they chose and if necessary to follow up with a clarification or probe (see Appendix G for sample semi-structured interview questions). I decided not to give participants the questions prior to the interview. I wanted them to draw on discursive resources which were immediately accessible (Gubrium & Holstein, 2012) within their science teaching and learning environment, without time to pre-package their answers and position themselves as 'other' than what they were in that moment. Instead, towards the conclusion of the interview I gave participants a basic outline of interview questions. This allowed them to look over questions and see if they wanted to add anything more, or to talk about an aspect that was important to them and their story but which I might have missed.

Students were interviewed about their learning during class time (brief, audio-recorded, conversational interactions). Lesson observations furnished time and opportunity to interview students informally and 'in-the-moment' about the teaching and learning taking place. The interviews were unstructured to allow me to adapt questions to each individual classroom context, and to gauge and respond to students' levels of receptiveness as I approached them. I found overall that students were very open to sharing their views with me. The often-humorous interactions with the students and the way they accepted my presence, graciously responding to what I sometimes felt were my intrusive little queries, made the whole observation and interview process a delight.

## 5.2 Phase one analysis

Data analysis in qualitative research is an iterative process where the researcher moves back and forwards between data and theory to recognise, assemble, categorise, code, theorise about, and reassemble data in the process of making sense of the material gathered in the field (Ezzy, 2002; Lawrence-Lightfoot & Davis, 1997). In this section I outline processes of data organisation and analysis for phase one.

### *5.2.1 Transcribing audio data*

Hammersley (2012b), Kvale and Brinkman (2009), and Taylor (2001b) see transcription as series of judgements and decisions which serve to construct data in certain ways. In this sense, transcription is a first step in any interpretive analysis of recorded voice data.

Phase one interviews with teachers were transcribed verbatim. Familiarity developed over three full listenings. The first was a global listening as I wanted to 'know' the data first and to note thoughts, interpretations, and questions before becoming focussed on the mechanics of the transcription process (Brinkman & Kvale, 2015). Next, I listened and transcribed in full. I experimented with voice recognition software and found this to be quite successful. The final listening was to check that the interview transcript was an accurate record of what was said. Other audio data from phase one, such as my own recorded reflections, conversations, interactions, and unstructured interviews with students were transcribed in a similar manner, although not always over three full listenings, as these tended to be brief and less complex.

When producing the transcriptions, additional details such pace, pauses, and non-verbal gestures were included if they were considered important in representing participants' meaning (Holstein & Gubrium, 2011) or important to the positioning and identities they reflected. I used standard punctuation with commas and full stops to mark micro-pauses and the end of a thought or statement. Longer pauses are indicated as '(…)'. I kept informal talk such as "I'm", "cos", or "yeah". I included information about context in brackets, such as the speaker laughing or emphasis on words where necessary. Although it was important to represent participants authentically, if hesitations and speech fillers were judged to be of little consequence to the overall meaning of the speech and judged instead to be distracting, they were removed (Pickering & Kara, 2017).

### *5.2.2 Compiling interview and observation data*

NVivo software was used to compile data in phase one because it allowed transcribed interview and observation data, photographs, video, and documents to be organised in one place and analysed as one data set (Corwin & Clemens, 2012; Kikooma, 2010).

To preserve confidentiality, data from participants within each case study school were assigned code names related to their role. For example, a curriculum leader became CL while teachers became TT1 and TT2. Students were assigned numbers as code names (student S1, S2…). Teachers and students were given different code names in the portrait because these code names were not tied to specific students or teachers from the case studies. Teachers became TA and TB, while students became SA, SB, SC... Other data such as document data were labelled and named according to the source. For example, NCEA achievement standards (AS) were labelled using the number and title of the standard and included details such as external or internal and number of credits.

### *5.2.3 Aspects of analysis and data (re)presentation*

In the sections below, I first detail aspects of thematic analysis used to examine the phase one sub-question: What *does* learning *look like?* I outline processes and rationales for data analysis and (re)presentation (Clandinin & Rosiek, 2007) of findings in the form of three separate case studies and an overall portrait of science learning. Next, I describe details of discourse analysis which guided an exploration of ways in which the discourse of 21st century learning was influencing science learning and reshaping possibilities for teacher and student positions and identities.

#### Thematic analysis: Three stories of science learning

Thematic analysis was used to develop and examine themes associated with the four identified macro-level elements. This deductive, thematic analysis pertained to the research sub-question: What *does* learning look like? For example, the analysis produced themes associated with the challenges of teaching science in flexible spaces, aspects to do with taught science curriculum, affordances and constraints associated with digital technologies, and aspects associated with internal and external assessments in NCEA. Categories were developed within these themes, for example, some of the categories assigned to the theme ‘challenges of teaching in flexible spaces’ included accessibility, noise and distractibility, and ownership of space. The thematic analysis was not wholly confined by the four macro-level elements. During coding, inductive codes were assigned to data segments that described a new theme observed in the text. For example, I inductively identified more general themes such as 'teacher professional development' and 'classroom management'.

NVivo software was used to structure and code data (Corwin & Clemens, 2012; Kikooma, 2010). I coded densely, and some portions of text were attached to three, four, or more nodes (themes). Dense coding at the beginning stages meant that after the first few interviews, no new nodes were generated. Subsequent steps included arranging the node hierarchy, pruning redundant codes, reassigning, checking consistency, and coding on the nodes to create categories (Richards, 1999). The software was helpful for checking thoroughness and reliability of my coding decisions. I would code on the node (into categories and subcategories), while at the same time checking data was coded into other relevant nodes (dense coding). As I worked through this process I was pleased to note I usually had already coded into all relevant nodes. Examples of thematic analysis are included in Appendix H.

Once coding was complete I used the software to identify key themes for each separate case study school, based on the frequency and distribution of nodes associated with each school. From this, I produced the three case studies as three separate stories of what science learning *looks like*, which are detailed in chapter six. The software also enabled me to identify key cross-case themes and to identify data which illustrated these themes, which I used to craft the portrait of what science learning *might* look like. In the section below, I describe the process of construction of the portrait.

**Cross-case thematic analysis: A picture of possibilities for science learning**

In the portrait I develop a more speculative picture of science learning in 21$^{st}$ century environments. In crafting this picture, I assumed "interpretive authority" (Pickering & Kara, 2017, p. 299) and employed the technique of portraiture as a method of data analysis and (re)presentation in a slightly different way. Rather than the portrait being a representation of one case, data were drawn together from all three case studies to create a single narrative, which as Hackmann (2002) and Lawrence-Lightfoot (2005) recommend, highlights successes while recognising limitations.

The narrative details the activities that took place over a 90-minute science learning session. Themes were chosen to depict experiences of teachers and students and the nature and interplay of four macro-level elements of a science learning environment. Data in the form of quotes from teachers and students are included to illustrate these themes and to ensure the portrait remains faithful to participants' voices (Lawrence-Lightfoot, 2005). These quotes are interspersed with material drawn from my observations and the overall portrait is narrated by me as researcher (Quigley et al., 2013). In acknowledgement of the impossibility of remaining "outside of" my subject matter (Willig, 2008, p. 10), "I" statements are used to recognise my "contribution to the construction of meaning throughout the research process" (Kikooma, 2010, p. 48).

Therefore, when reading the portrait, it needs to be remembered that the learning space and episodes described are a storified version, composed by borrowing the best (and sometimes worst) features from each case. Teachers and students in the portrait are fictional characters grounded in a blend of participants' data. Mason's (2002) concept of resonance provided the metaphor I used to select data and craft the characters and storyline. For example, the descriptions of the two different teachers in the portrait are intended to represent the essence of the similarities and differences I observed across the cases. The description of the physical space embodies an architecture which fuses the most enabling features of all spaces across all schools I observed. In this way, I used portraiture to reflect a reality but also to project an ideal. In keeping with a constructionist stance, my intention was to offer an emblematic but hypothetical representation of what teaching and learning might look like a 21st century learning environment. The portrait serves as an overall answer to the overarching theoretical question and phase one sub-question, and as a bridge to phase two.

**Discourse analysis: Possibilities for teacher and student positions and identities in science learning**

As noted in chapter two, social constructionist Vivien Burr (2015) asserts that "Discourse is at the heart of social constructionism" (p. 224). Discourse analysis is compatible with a constructionist theoretical perspective. In this study, while thematic analysis informs the development of findings in the case studies and portrait in more descriptive, explanatory form, a more theoretical discourse analytic lens was applied to inform discussion of discourse, positioning, and identity in interpretive discussions. The interpretive discussions are presented at the conclusion of sections and subsections of case studies and portrait.

Parker (2004) distinguishes between thematic and discourse analysis, where thematic analysis focuses on sorting and categorising data around themes which are used to illuminate certain phenomena, while discourse analysis is generally concerned with "how words and phrases are linked at the level of discourse" (Parker, 2004, p. 99). In other words, discourse analysis is concerned with how the uses and effects of language and discourse produce meaning and offer certain ways of being in terms of positions and identities, while excluding others (Graham, 2011).

There are many forms of discourse analysis and discourse theory which can be informed by different theoretical frames. Various forms of discourse analysis are associated with social constructionist research, and the approach chosen varies depending upon the ontological and epistemological orientation of the researcher and on the research purposes (Burr, 2015; Gee, 2014; Willig, 2008). Burr (2003, 2015), Holstein and Gubrium (2000), Wetherell et al. (2001), and Willig (2008) identify analytical approaches associated with forms of social constructionist research that include conversation analysis, Foucauldian discourse analysis (FDA), critical discourse analysis, interpretive repertoires, and discursive psychology.

In applying a discourse analytic lens in this research, my approach was most similar to Foucauldian discourse analysis (FDA). FDA is influenced by the work of Michel Foucault and poststructuralist writers such as Jaques Derrida (Burr, 2003; Willig, 2008). Using a process of FDA, a researcher is interested in language, but is also interested in the physical or material conditions and social structures that shape the context for language use (Burr, 2003). According to Burr (2015), FDA "is concerned with the way discourses produce a sense of 'self', or subjectivity, through positioning" (p. 192). Similarly, Willig (2008) describes FDA as a focus on "what kinds of objects and subjects are constructed through discourse and what kinds of ways of being these objects and subjects make available to people" (p. 96). Put another way, discourses bring with them different possibilities for what a person can do, and what they are able or expected to do for others.

Willig (2008) sets out steps for discourse analysis which were useful in guiding my thinking in this research (p. 115-117). In asking and answering the overarching research question, I focussed on conditions of possibility constructed at the macro level by four identified elements of curriculum, assessment, physical space, and digital technologies. I considered the effect for teachers and students at the micro level in terms of possibilities and limitations in what they perceived they could or could not do. For example, I identified ways in which the language of curriculum documents and NCEA achievement standards constructed different possibilities for how teachers and students might teach and learn (Locke, 2005). The notion of positioning within discourse was important because, according to Davies and Harré (1999):

> once having taken up a particular position as one's own, a person inevitably sees the world from the vantage point of that position and in terms of particular metaphors, storylines and concepts which are made relevant within the particular discursive practice in which they are positioned. (p. 35)

That is, the uptake of particular positions within different discourses means teachers and students experience themselves and perform as certain *types* of teacher and student, and in doing so, construct certain identities (Edley, 2001; Hall, 2001; Søreide, 2006). I focused on pre-identified discourses of 21st century learning and traditional science schooling. I examined possibilities for 'who' and 'how' teachers and students of senior science might be in terms of identities enacted within these discourses. Examples of discourse analysis are included in Appendix H.

Next, I move to describe research methods and analysis for phase two. Where these approaches are similar to phase one, I refer to the sections above which pertain to these. Where they are different, I explain further in the sections below.

## 5.3 Phase two research methods

### *5.3.1 Action research*

The phase two sub-question asks, 'What *could* learning look like?' The aim was to actively allow the discourse of 21st century learning, with a focus on personalised learning using science inquiry, to shape teacher and student actions and identities, and to reflect on possibilities and constraints for this approach. To address this question, phase two involved a collaborative action research inquiry into models and possibilities for personalising NCEA science learning in FLS.

Principles of action research ask us to "act in the direction of the imagined solution" (Atkins & Wallace, 2012, p. 137), and an action research approach is consistent with aims of contributing to knowledge through productive, practical action (Bradbury, 2015). Action research is interventionist; it seeks transformation. From a social constructionist perspective, collaborative action research can be seen as a process of shared construction and collaborative meaning-making (Gergen & Gergen, 2015). It privileges knowledge and experiences of teachers and students and is participatory in the sense that it involves doing or researching *with* rather than *for* or *about* (Bradbury, 2015; Levin & Greenwood, 2011).

Action research is a type of systematic inquiry which involves identifying issues or areas of focus, collaboratively deciding upon, designing and undertaking an intervention, carrying out data collection and analysis, and finally, evaluating outcomes (Cohen et al., 2011; Efron & Ravid, 2013). It is similar to case study research in that it seeks to observe effects in highly complex, social contexts. Also similar to case study research, appropriate instruments of data collection for action research include interview, participant observation and document collection (Bradbury, 2015). According to Kemmis, Taggart, and Nixon (2014), action research connects theory and practice. In other words, an action research approach can mean consciously using theory in practice as well as theorising *about* practice.

Action research can "start small" (Kemmis et al., 2014, p. 47) to allow opportunity for "learning by doing" (p. 2) as participants navigate new and different ways. Therefore, it makes sense that action research can be situated as separate undertakings within successive cycles of planning, acting, observing and reflecting, which are informed by previous cycles (Kemmis et al., 2014; Torrance

& Pryor, 2001). In phase two, I joined with a teacher and a group of senior science learners from a phase one case study school to collaboratively investigate possibilities for personalising science learning across three cycles of action research. The three cycles corresponded with successive units of science teaching, learning, and assessment during the school year, and enabled us to "start small" as we investigated the use of different types and levels of inquiry learning to facilitate personalised pathways in senior science.

### *5.3.2 Identifying and joining with participants in Phase two*

In seeking to join with a teacher and school for phase two action research, I needed to consider which of the phase one case study schools to approach. Each school involved a different context and learning environment, with different challenges and affordances. A decision was easy in the end, however, as I decided that if I wanted to push the boundaries in investigating possibilities for personalised learning, it would be most ideal if I could work with the school which was, in my view, already furthest 'along the track' in terms of these approaches. The design of the second case study school's physical learning spaces and the inquiry philosophy of the school, as well as the flexibility in learning already offered to students, meant this school was my first choice as I began the phase two recruitment process (see section 6.2).

After seeking permission for a second phase of research from the Principal of case study school two (Appendix I), I was fortunate to be able to work with the Science Learning Area Coordinator (LAC) and her level two NCEA science class for the collaborative action research (see Appendices J, K, and L for information and consent forms given to LAC, students, and parents). From this point on I refer to the LAC in phase two action research as 'teacher', recognising her role of level two general science teacher in the collaborative action research.

### *5.3.3 Data generation in Phase two*

In phase two action research I was involved with one school during an eight-month period, beginning in March 2017 and ending in November 2017 when students left school to begin external NCEA examinations. Science class was scheduled either two or three times per week and during the action research I attempted to visit at least two sessions per week, participating, observing, and recording where appropriate. I made a total of 48 visits.

The predominant method of data collection in phase two was participant observation (as described in section 5.1.4). This is because I was spending extended amounts of time with the class and was acting both as researcher and class member in my interactions with students and teacher. In addition to field notes, my own recorded reflections, documentary data, photographs and video, and audio-recorded natural talk in interactions, I relied on unstructured interviews with teacher and students. For example, I recorded reflective conversations between myself and the teacher before, after, or during classes as spontaneous, ongoing interactions. I recorded my curious questions and discussions with students about happenings ‘in the moment’. Although student interviews were unstructured in that they were not formal or scripted, I was focussed on students’ positioning as 21$^{st}$ century learners, and therefore focussed on students’ learning choices and progress as self-directed learners.

I made field notes where I recorded critical incidents and my thoughts about these in the form of a (mostly voice-recorded) reflective diary (Kemmis et al., 2014). I collected relevant NCEA assessment documentation and took copies of any other relevant documentation such as worksheets given to students. I also took photographs of student work where applicable. I often recorded the teacher’s addresses to the whole class at the beginning of sessions, and recorded the teacher speaking to and teaching groups and individuals. When I could without feeling too intrusive, I recorded brief video of happenings in the lessons and audio recorded students’ learning conversations with each other.

Finally, a challenge in action research is how to measure exactly what has been achieved. To what extent is it possible to attribute causal effect to the intervention itself, when working in a complex, dynamic, environment where many other possible factors may impact outcomes (Cohen et al., 2011; Goodnough, 2011)? In phase two as part of reflecting on student progress and achievement outcomes, quantitative data in the form of students’ NCEA assessment results were also collected.

## 5.4 Phase two analysis

### *5.4.1 Transcribing and compiling data*

In phase two transcription I used a process similar to that described for phase one in section 5.2.1 above. I would listen to all audio from each session before selectively transcribing interviews, conversations, and other recordings of teacher and students' speech. This was necessary as the recordings captured a large volume of material which I deemed to be irrelevant or not able to be transcribed. I also transcribed my voice-recorded reflections.

All transcribed data was inserted under the relevant date into a research diary. This research diary was the repository for other notes and accounts of what happened in each dated session, such as movement of teachers and students in and around spaces, or which students were absent and why. I also used this diary to note wonderings and reflections which required action going forward, such as questions I wanted to ask the teacher or students. I added notes about documents and links to document data. This diary became the central organising tool for analysis in phase two.

In the initial stages of phase two and prior to the action cycles beginning, I focussed on getting to know students and collecting baseline data such as other subjects studied, career interests, and interest in science learning. I was working with a large student group and had to put systems in place to keep track of the data I was collecting. To do this I built a summary table which I added to after each session. This process meant I could see quickly who I needed to focus on to fill in any gaps.

As the research progressed I decided to work more closely with a smaller group of eight students and to tell their stories in more detail where appropriate. I selected these students as of interest due to the pathways they were taking and because they reflected something of the diversity within the class. Although I followed these eight focus students more closely, it was usual for me to interact at least once with most individuals in the class, each session.

During the initial stages of phase two, I offered students the option of choosing a pseudonym, or if they preferred, I offered to choose a pseudonym or code name for them. Most declined to choose a pseudonym. Two of the eight focus students wanted me to use their own name. I coded non-focus students by the first letter of their name to enable me to refer to them easily (student B, student L). Where students' names had the same first letter I added a number (student M1, student M2). Because I was working closely with the eight focus students, and because two of them wanted their own names used, I chose pseudonyms for the other six. Similar to phase one, document data were labelled and coded according to source.

### *5.4.2 Aspects of analysis*

The phase two thematic analysis relates to the phase two sub-question (what *could* learning *look like*) and to the (re)presentation of data and findings in the form of a report on actions and outcomes of three cycles of collaborative action research interventions. Following a similar format to phase one, sections and subsections of action research reports are concluded with interpretive discussions which are informed by aspects of discourse analysis.

**Thematic analysis: A story of personalised science learning**

In phase two, by living with the teacher and students over the year, I was able to record their stories of science learning (Bath, 2009; Connelly & Clandinin, 2006). I would analyse data from each dated session in the research diary in an ongoing manner, usually shortly after each visit. Patterns and themes became apparent within each cycle, and across all cycles, as I worked through the research diary.

Data are (re)presented as chronological narratives where I recount teacher and student actions over the timeframe of the task for each cycle. Because I was interested in students' positioning as 21$^{st}$ century learners, I decided the analysis must focus on individual student outcomes if it is to have something to say about students taking up independent, self-managed identities in personalised learning environments. I decided to tell the stories of the eight focus students as running narratives across each cycle. Data collected from other students was included where relevant or exemplary. Presenting language data, descriptive data and student achievement data in a narrative form allowed me to document 'real life' progressions and to highlight key themes in each cycle (related to four elements) while simultaneously reporting on outcomes of the action research interventions.

Each cycle begins with a description of the action research intervention. In exploring what learning *could* look like, phase two explored different approaches to personalising learning for senior science students working within the NCEA assessment frame. The aim was firstly to investigate how and why students were able to make choices within different levels of science inquiry to personalise their learning and what types of support they might need. Secondly, the aim was to document learning progressions and analyse the impact of the four identified macro-level elements on student learning. Data are presented to show students acting as choice-makers and to describe their progress to task completion. Data also show teacher actions as she supported students' learning. Elements are represented by themes associated with curriculum choices, the influence of NCEA assessment on students' learning and choice-making, and the use of physical space and digital tools to afford personalised approaches.

**Discourse analysis: Possibilities for teacher and student positions and identities in science learning**

Phase two action research shows what could and did happen when students and teacher were intentionally positioned and repositioned in 21st century personalised science learning environments. The interpretive discussions which conclude cycles and sub-cycles of phase two research first present quantitative student achievement data because this information was integral to the evaluation of the impact of the action research interventions. Secondly, the interpretive discussions present aspects of discourse analysis which was employed to take a deeper look (Leinhardt & Steele, 2005) at science learning in terms of teacher and student positions and identities, in a manner similar to the processes of analysis described in section 5.2.3 above. Specifically, the analysis focussed on students' positioning as choice-makers. The nature of choices offered within different levels of inquiry and reasons for student choices were analysed in terms of what/where/how/with whom to learn. The interpretive discussions highlight the way the macro-level elements constructed possibilities that did or did not support teacher and students to take up different identities associated with offering and accepting choices in personalised science learning.

## 5.5 Establishing quality

Quality in research means the design, decisions, and conclusions of the study can be trusted (Mutch, 2005; Potter & Kustra, 2011). Concepts such as reliability and validity are not appropriate in social constructionist research, which is considered to be historically, culturally, and contextually specific. Participants and researchers' descriptions and interpretations are understood to provide only one account of reality as it could be known (Burr, 2015). Instead, the concept of legitimacy can be used as a measure of quality. The concepts of usefulness and fruitfulness (Burr, 2003; Taylor, 2001a) can also be used as a measure of quality.

According to Burr (2003), usefulness and fruitfulness can be used to describe the "power of research to generate theory developments and novel explanations" (p. 159).

In this research, legitimacy is centred around the concept of trustworthiness, which is defined as making the "practices of interpretive inquiry visible and therefore auditable" (Ceci, Limacher, & McLeod, 2002, p. 716). According to Goodnough (2011), interpretations of trustworthiness include: credibility, transferability, dependability, and confirmability (p. 31). Researcher reflexivity, participant validation, and giving a clear account of research decisions and processes (Burr, 2003; Cohen et al., 2011) are strategies for establishing trustworthiness in this research, as is careful consideration of ethical issues. In the sections below, I explain each of these four aspects.

### *5.5.1 Researcher reflexivity*

"Reflexivity is the process of reflecting critically on the self as researcher, the human as instrument" (Lincoln, Lynham, & Guba, 2011, p. 115). The researcher must view the research as a co-production between themselves and the participants and acknowledge their own intrinsic involvement in the research process, especially as "no human can step outside of their humanity and view the world from no position at all" (Burr, 2015, p. 172). For example, as discussed above in section 5.1.4, my past experiences and my assumptions about teaching and learning influenced the interview questions I asked. I constantly sought to acknowledge and understand my influence on the construction of meaning throughout the research process (Kikooma, 2010) and recorded these thoughts and reflections in observations notes and in my research diary.

I reflexively monitored my interactions with participants and was aware of how I positioned myself as a researcher. As I was entering the contextually specific fields of secondary science education, NCEA assessment, and flexible learning spaces, it was necessary to have a certain amount of what Lock and Strong referred to (after Wittgenstein's grammars and language games), as "insider knowledge" (2010, p. 161). If I did not already have familiarity with the words, grammars, and meanings of secondary NCEA science teaching, then the interviews and observations might have merely entailed the process of my education into the 'game', and due to time limits might have gone no further. My previous experience as a chemistry teacher and teacher educator enabled me to present as an experienced discourse user, thus I constructed myself as a knowing group member (Koro-Ljungberg, 2008). I was able to gain a basic familiarity of the local language of flexible learning spaces by reading school websites and from early visits to flexible learning space schools. By my (conscious and intentional) use of terms such as 'the commons' and 'breakout space' I was able to position myself as knowledgeable at the outset in this aspect as well. Sometimes I was a little too successful and it was an interesting exercise observing the extent to which the teachers spoke 'the lingo' and assumed shared knowledge, leaving me nodding knowledgably along and looking up acronyms and definitions later.

Thinking back to the teachers in Carlone et al.'s (2010) study (section 2.4.3) who were overtly positioned as innovative boundary pushers in the recruitment stage and who later became 'tempered radicals' in the findings, I remained mindful of how I was positioning teachers as prospective participants, and of the impact this would have on the type of data that would emerge. I was cognisant of Burr's assertion that within a social constructionist frame, researcher influence and positioning of participants (and them of me) is unavoidable because:

> One cannot avoid subject positions, the representations of ourselves and others that discourses invite. Our only choice is to accept or reject them and if we accept or are unable to resist we are locked into the system of rights, speaking rights and obligations that are carried with that position. (2003, p. 111)

In effect, I was 'hailing' (Drewery, 2005) the science teachers, curriculum leaders and students as certain types or categories of person: as innovative, as capable, as a leader. I was offering them positions from which to speak which ultimately would influence their performance in interview and even when being observed (Koro-Ljungberg, 2008). For example, in my first participant observation sessions in phase one, I would ask students "what they were doing". These were NCEA classes and this question invariably led to answers in the form of descriptions of the particular achievement standard that the students were "doing". In attempting to move away from the dominance of the assessment frame, I tried to open options for answers from a different frame and changed my questions to: "What are you learning about today?" Answers to this question often circled back to the achievement standards but also proffered different insights.

### *5.5.2 Participant checking*

A researcher cannot assume their viewpoints and interpretations are identical to participants, therefore, according to Lock and Strong (2010), what is to be counted as reality must be decided by a process of negotiation (p. 321). I conducted second interviews with all teachers in phase one and at this time sought to ensure my observations and analyses reflected their perceptions and experiences (Corwin & Clemens, 2012, Kornbluh, 2015; Maeng & Bell, 2015). Teachers were first emailed a copy of their interview transcripts and asked to review them. Then in the interviews, I asked participants if they were happy with the way the transcript represented them. They were specifically asked if there was anything in the transcript they did *not* want used. I highlighted quotes I knew I wanted to use in data presentation chapters, especially if I thought they may represent the participant in a negative light.

For each school, I also developed a school story which was given to teachers. This took the form of a mini case study including information about context, teachers, and students, as well as a description of the school's learning philosophy, resourcing, and physical space. I then used observation and interview data to present a narrative depicting my impressions of a single, 'typical', science session in that school. Participants were asked to comment on their school story and the themes within. While it would not have been possible to give a complete account, I wanted to know if their story captured a likeness and whether it represented something of the essence of their experiences (Kornbluh, 2015; Lawrence-Lightfoot, 2005; Mason, 2002).

In phase two the teacher was provided with action research summary notes of our initial decision-making process and of my ongoing evaluations for each cycle. I checked with the teacher on an ongoing basis that she was happy for me to use any data and quotes that were directly related to her. In addition to our ongoing conversations and updates, I made regular checks that she was still 'OK' with having me in her class and with what we were doing.

In both phase one and two it was not feasible to check all direct quotes with each student from whom I collected data, however, whenever I began a conversation with a student or group of students, I always made sure to indicate that the recorder was on and asked if they were happy for me to continue. In phase two where I focussed closely on eight selected students, I checked specifically with them to ensure they were 'OK' with me using and including their data. All were happy for me to use their data.

### *5.5.3 Transparency in decisions and processes*

Trustworthiness can be enhanced if the researcher is able to give an account of decisions, actions, problems, and solutions at each stage of the research (Altheide & Johnson, 2011). This includes clear explanation of methodology as well as selection of and justification for the intervention. As researcher, I aimed to leave a clear audit trail, showing how the analysis was carried out and demonstrating how my interpretations evolved from the data (Burr, 2003; Cohen et al., 2011). In this research, I aimed to be systematic in recording processes of observation and in documentation such as transcription of data. I also sought to be explicit in explaining how data were analysed and how outcomes were evaluated.

### *5.5.4 Ethical considerations and actions*

I sought and gained ethical approval for the research from the Faculty of Education Research Ethics Committee at the University of Waikato.

Ethical decisions are multi-layered and not always straightforward. Research ethics and research guidelines (University of Waikato, 2015) compel the researcher to consider issues of benefit and potential harm, and like a pre-flight check (Guillemin & Gillam, 2004), offer protection for all involved. Producing a trustworthy piece of research necessitates careful adherence to ethical principles in every step of the research process. Researchers must be honest and transparent, remaining open-minded and reflexively aware of the effects of the research on participants. Most important to me was a culture of respect and care, and a concern for the people in my project as I remained conscious of the impact my presence had on them.

Tolich (2001) argues that there is no "hierarchy of ethical principles" (p. 6) and if there are cases where one principle is not fully applicable, other principles must be used "in concert" (p. 6). The fundamental principle of 'first do no harm' influenced my decisions during times of uncertainty. The definition of 'harm' is particular to each individual, but for myself, if an action felt wrong or uncomfortable, or if I thought it would impact negatively on participants, I didn't do it. As examples, I did not use video recording very often because it felt too intrusive. As secondary schools compete for student numbers and reputation, I was careful not to compare schools in conversations, especially negatively, or to be drawn into competitive put-downs of other schools. Another key consideration in this research was the issue of time demands on participants. I tried to be as economical as possible with the time I asked for and resisted temptation to ask for time in excess of what was originally agreed.

Freely given, informed consent is central ethical principle. It recognises participants as autonomous beings who are capable of assessing for themselves the risks and benefits of participating in research, and subsequently choosing if they want to take part (Herrera, 2001; Howe & Moses, 1999). Informed consent means explaining the research intentions and implications of being involved in accessible language, ensuring rights to withdraw are understood, and explaining limits of confidentiality. Freely given consent means no coercive actions are employed during the process. In phase one I was working with large numbers of students across the three case study schools, with combined classes numbering 50-60 students. These year 11 students were mostly 15 years and younger, therefore, information and consent letters needed to be taken home for parents to sign and return. I felt tension between my desire to gain consent from as many students as possible and being overly pushy in reminding students about return of parental consent forms. As not all students returned these, and as I was still learning names, I asked teachers to put a sticker on tables in front of each student who had volunteered to participate and who had parental consent.

In phase two the student consent process was more straight-forward as I was working with a single group of year 12 students, over an extended time-period. I explained my research to the class and invited them to participate, before distributing information letters and consent forms. Many of those who were 16 years signed the form immediately. A few who were 15 years old took the form home to be signed by parents. Of a starting group of 27 students, just two students declined outright to participate. As I built relationship with these two students over the year, I suspect that if I had approached them again the reply would have been positive, however, I respected their initial decision.

I was constantly aware that my role as teacher and researcher placed me in a powerful position in terms of interacting with students. Because of it I had a footing (Harré & van Langenhøve, 1999) which allowed me to enter conversations with students at will, simply by walking up to their desk and initiating this, even as they were working or interacting with their peers. This too, felt intrusive at times, and some days during phase two research I did not interview or record at all. Instead, I just observed or helped students with their work and chatted about life.

Another issue was the distinction between anonymity and confidentiality. A promise of anonymity means information provided by the participants should in no way reveal their identity (Bell, 1999; Cohen et al., 2011; Howe & Moses, 1999). It was not possible to guarantee anonymity in this research, and I was explicit at the informed consent stage when explaining anonymity and the limits of confidentiality. The small number of target FLS schools means participants might be identifiable based on broad descriptors such as enrolment numbers, decile rating, or co-education. Similarly, anonymity was not guaranteed within a small science department where people held named roles such as curriculum leader or teacher of level one science. On the other hand, every effort was made to provide and maintain confidentiality. All identifying details of participants remained confidential and stored in a secure location. Code names and pseudonyms were used, and any quotes used in the written analysis were anonymised, although I was careful to honour students' requests. As an example, two of the focus students in phase two wanted me to use their own names and one, who seemed to be excited to be part of a research story, asked me to email the data I had about him – which I did.

As collaborative action research seeks to effect change via a shared undertaking, it can invite power issues. Questions could be raised around who has control of the research (Cohen et al., 2011; Efron & Ravid, 2013) and how it is reported. In all stages of phase two I endeavoured to proceed ethically, carefully, and to take an inclusive and participatory stance, respecting participants' interests, agency and autonomy. Again, the concept of researcher reflexivity was important; I needed to maintain a "self-conscious awareness" of the effects I had on the research and on participants (Cohen et al., 2011, p. 359). In phase two I was more closely involved and spent more time with the teacher talking about the intervention and associated activities, as well as reflecting on and evaluating the outcomes. I endeavoured to do this at times that suited the teacher. I checked with the teacher regularly that she felt comfortable with the research and with my presence. She was continually positive and said she enjoyed having my support. I also regularly checked with students that they felt comfortable with my presence. Although it is hard to imagine that they would have the gumption to tell me to go away, their spontaneous, *"Hi Miss, where were you yesterday"* if I missed a class, helped me to know I was welcome.

The research process is unpredictable and does not always go to plan. For instance, I often found myself amused at the minor glitches that occurred during the process of conducting semi-structured interviews. Unfailingly, before the 'start' of the interview, and while I was busy reiterating ethical procedures and reminding participants of their rights, they would start talking and I would miss 'good data' as the recorder was not on. I would then quickly make a note to come back to the issue once the interview had begun and recorder turned on. In another, more significant example where things didn't always go to plan, a dilemma arose between a statement I made in my consent letter to students: "I will not judge your work" and my desire to contribute to lightening teachers' workload. When asked to moderate students' work for internal assessments, I did, as I was familiar with the standard (having just worked with the class as they completed it). I discussed the issue with my chief supervisor and we decided I was moderating the teacher's judgement as much as the students' work. I did not moderate any more work after that. Guillemin and Gillam (2004) examine the impact of issues such as these, where real but unanticipated tensions and dilemmas arise between "procedural ethics", and "ethics in practice" (p. 264). Guillemin and Gillam suggest that researchers need to maintain a sense of reflexive awareness of "micro-ethical dimensions of research practice" (p. 278).

What do participants stand to gain from being involved in research? In phase one, planning time for interviews with me and the possible pressures of having an observer in the classroom added to the workload teachers already carried. I was constantly looking for ways to help and give back. I did this by sharing ideas and resources, and by helping students with their work where possible. I was pleased to observe that teachers enjoyed reading their school stories and from their comments, I felt they that were at least a little encouraged by the process and by my interest. In phase two the teacher was interested in joining with me for her own professional development and as a step towards her own eventual postgraduate study. As I was involved longer term and at school more often, I was able to contribute on a more meaningful level. I was asked by a deputy principal for input on a school-wide review of inquiry learning and was happy to oblige. I helped a student write an application for a Royal Society Māori Science scholarship. I was asked by the teacher for give feedback on various documents she was required to write. The teacher was able to use the participant checking notes I supplied about the action research as a basis for writing up her teacher inquiry for her appraisal.

In summary, the process of establishing quality in this research relies on an interpretation of trustworthiness as making visible the processes used for assuring credibility, transferability, dependability, and confirmability. These include researcher reflexivity, participant checking, giving a clear account of research decisions and processes, and ensuring ethical conduct (Burr, 2003; Cohen et al., 2011).

## 5.6 Chapter summary

This research was designed in two phases to inquire into the overarching research question and sub-questions relating to science learning in the ‘now’ and what might be possible. This chapter has detailed the application of case study, portraiture, and action research approaches within a social constructionist theoretical frame. It detailed instruments used for data collection of interview, participant observation, and document collection. Data analysis employed thematic and discourse analysis. This two-pronged approach to analysis enabled the identification of important categories and themes. As well, it enabled an examination of discursive affordances and constraints on teacher and student positions and identities. Establishing quality in this research meant employing strategies for ensuring legitimacy and were centred around concepts of trustworthiness: researcher reflexivity, participant checking, transparency in descriptions of research decisions and processes, and ensuring ethical practice.

I move now to present data and findings from phase one in chapter six. Chapters seven and eight present research data and findings from phase two.

# Chapter six: Phase one case studies and portrait

This chapter presents data and findings from phase one. First, in sections 6.1 to 6.3, data and findings from the three schools are presented separately as bounded, mini-case studies. Each case study reports on contextual details about the school and introduces the teachers involved. Data is presented to emphasise key themes particular to each case and to illustrate what science learning *looks like* in each school. Section 6.4 summarises findings across the three cases. Lastly, the technique of portraiture is used in section 6.5 to provide an overall representation of what science learning *might* look like. Each separate case study and the portrait is concluded with an interpretive discussion which considers how the four identified elements work to produce different possibilities for teacher and learner identities.

## 6.1 School one case study: Adapting to a new reality

The key theme highlighted in this first school case study is one of teacher transition to new spaces. Data are presented to illustrate ways in which the dynamics of redesigned 21st century learning spaces, teacher conceptions of science as a subject, and accountability concerns associated with assessment under NCEA impacted and concomitantly repositioned teachers as they transitioned to a new FLS space.

### *6.1.1 Contextual information*

**The school**

The case study involved the science curriculum leader and two teachers of two year 11 mixed-ability classes of science students in a low-mid decile (low to mid socioeconomic), mid-size (900 students), co-educational, urban state secondary school (Ministry of Education, 2018d). The school was one of the first in New Zealand to undergo a rebuild to flexible spaces, as opposed to a new school build on a new site. The buildings were rebuilt following problems with leaky building syndrome[2].

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[2] Leaky building syndrome occurs when the design or construction of a building fails to provide adequate water tightness. Water can penetrate but not dry out, causing high moisture levels and rot. This eventually weakens the structure of the building and causes health hazards such as the growth of dangerous fungi and moulds. http://www.resolutionarch.co.nz/faqs/.

The school community subscribed to a philosophy of meaningful, connected, contextual, and cross-curricular learning, especially at the junior level (years nine and ten). For example, year nine students in maths, science, social science, English, and physical education might learn under the umbrella theme of Body Systems in groups of 80 students, co-taught by a team of three or four teachers from different disciplines. In the case study year, students from years 11-13 studied separate NCEA subjects such as science, English, and mathematics as separate classes, although senior leaders were investigating possibilities for theme-based learning in senior school. Science at year 11 was compulsory for all students.

**The space**

Prior to the new build, science classes happened in traditional laboratories, with tables in the middle of the room, and benches, gas taps, and equipment around the outside. Whereas in the old school there were six laboratories with each teacher taking responsibility for one, in the new spaces there were four, shared, dedicated practical laboratories which were attached to larger learning commons. There was no seating in the new labs. All equipment was stored centrally and was requested from the lab technician and collected prior to class. Teachers booked the laboratory ahead of time and sometimes only moved in for a 20-minute practical session before moving back to the commons.

Each learning commons area accommodated 80 students, or up to three classes in total. An open L-shaped space was large enough for two classes. A ‘fish bowl’ classroom (the analogy is indisputable – a rectangular glass-walled box) intruded into the corner and was usually occupied by a single class. A smaller breakout room (maximum ten students) was situated beside the fishbowl. In the main space, two sets of data projectors and smartboards were fixed to opposite walls. Smaller portable whiteboards stood to the side. Tables were mostly round, seating about four students, distributed throughout the space. Semi-visible through small windows along one wall of the commons was a locked laboratory space.

### *6.1.2 Introducing case study teachers*

In the case study year (2016), the two teachers of two, year 11 science classes were sharing a commons space together for the first time. A year 12 class worked in the fish bowl with their teacher and there was no interaction between this class and the year 11 classes.

**Science curriculum leader**

The curriculum leader (CL) had 15 years teaching experience, arriving at the school two years prior to the rebuild. CL noted that many teachers were happy and comfortable in their old laboratories, where each had their own space furnished with their own equipment. This made the transition to new spaces more difficult.

> *Each person was responsible for a lab and that was a system that people liked an awful lot. The transition to the shared space definitely brought a lot of challenges about using space.*

The new, walk-in, walk-out labs challenged teachers' ideas about what science teaching should be like.

> *There was quite a significant grieving period for teachers as they realised a lot of skills that they developed are no longer viable with the new setup. Yeah, it's still challenging for staff.*

CL provided leadership through the change process, which he described as difficult but necessary, arguing that there was a need for change.

> *The old system might well serve the teachers, but does it serve these kids who are growing up in a society that's changing and it's so dynamic and it's moving forward quickly? When you sit down and ask yourself that question it's quite easy to come to the conclusion that yes, schools need to adapt and schools need to change.*

CL also acknowledged that teaching in the new learning spaces challenged his own previously established identity as an innovative teacher.

> *You talk about change to innovative learning spaces, but you know, innovation's always been there, and I'd say I was innovative in a way...but yes, since the flexible learning spaces, a lot of those strings in your bow, if you like, have changed.*

**Teacher one**

Teacher one (TT1) had 18 years of experience, 11 of them in the case study school. The internal professional development that was provided did not seem to meet TT1's needs for understanding drivers and rationales behind the transition or for learning how to be a better teacher in the new spaces.

> *They talked a bit about collaboration with other teachers and things like that, but to be honest I didn't really know why we were doing it. I thought it was the Principal's directive, I thought it was his idea, and his baby, but then later on, I found out that the government is pushing this as well. I don't like it, but that's what it is*.

> *They talk about theory a lot. Well, I don't want to know about the theory, I want to know- what can I do in my class to make learning better*?

He did not like the new environments and experienced the transition as a stressful adjustment.

> *I think I had a headache probably four out of five days for that first term that we were in here cos I just I had difficulty handling it.*

TT1 identified strongly with his subject area, telling me as he introduced himself: *"I am Chemistry".* He took pride in the execution of a well-structured lesson, engaging his students with discussions and often spontaneous demonstrations. In his old laboratory space, he saw himself as *"quite a good teacher"*, able to use skills honed over many years.

> *I guess because I taught for…probably 20 years in a cellular classroom, you know, I started off as probably a not so great teacher, and I've gotten all these things over 20 years, and now I got this new environment…*

TT1 felt that he was more able to be flexible in his own (old) laboratory, where he was surrounded with his apparatus and equipment. In the new shared spaces, unable to practise as he used to, he felt he was not as effective as a teacher.

*The way I used to be, I (can't) do it, and, I guess feeling that, 'Oh I'm not as effective as a teacher'.*

*I find these innovative learning environments less flexible than a cellular classroom or a laboratory.*

**Teacher two**

TT2 was in her first year of teaching, having moved directly from high school to complete her degree and teacher training. TT2's practicum experiences were in single-cell laboratory spaces, where she worked with associate teachers who were each in charge of their own space.

*Each teacher had their own room so that was quite cool, so you could set up your room how you wanted it.*

TT2 perceived her preservice teacher training as not offering any specific preparation for flexible, open spaces.

*We never went into anything really specific for open plan learning, I don't think it was ever really mentioned. We were learning stuff about behavioural management and everything, which you can apply to the pods, but I guess it's also different because...behavioural management, you've also got other classes in the room.*

Nevertheless, she described herself as prepared to be eager and enthusiastic, and as such she found it relatively easy to adapt.

*I'm a first-year teacher, I've been chucked into each school and it's all been different, and I thought, it's just something new again.*

### *6.1.3 Steps in a new direction*

In the following section, data is presented to emphasise the way a transition to new 21$^{st}$ century learning spaces was in tension with traditional science teaching practices. This both challenged and changed science teachers' practice identities.

**Science as a knowledge-based subject**

In the new spaces, some time-honoured assumptions about 'good' or 'effective' science teaching were being troubled. Teachers were not so readily able to take up traditional science teacher identities. These traditional identities included teacher-led approaches, such as teaching science as a knowledge-based subject and the value placed on spontaneous demonstrations and practical work.

Both TT1 and TT2 perceived transmission-based teaching as most efficient in executing a duty to help students *"get through"* the knowledge-based external examinations in NCEA.

> *TT1: There's a lot of knowledge that needs to be conveyed…like…we've got a certain amount of time. If you just let the kids find out about genetics on their own, it's going to take too long.*

> *TT2: It's quite a lot of stuff that we've got to get through for the externals in a short amount of time…it's bad for my teaching…there is a lot of content, teaching them the content.*

> *TT2: It's almost like cramming and they have got to remember everything for the external…*

TT1 felt that repetition was an important strategy for helping students to remember concepts for external assessments. In the old spaces, his identity as an effective teacher was built in part from being able to have fun with students and being able to motivate them by revisiting content using games and quizzes. However, he found the 'quiz-master' position was less achievable in the new spaces. Fun often makes noise, and issues of 'distractibility' were a key concern. TT1 was also conscious of judgement from peers.

> *TT1: I used to play games with my kids, have fun, but that makes noise on the other side and disrupts the other ones, and another adult in the room and you don't want to look like an idiot in front of your peers.*

Both TT1 and TT2 found their preferred teacher-led or transmission-based approaches were less feasible in the new spaces. They were aware of each other and of increased noise levels.

> *TT1: I would like it to be more teacher-led but I found with the new learning environment I have to do less of that, cos you just can't talk all the time, because there's another class next to you. It's just too noisy for them to hear. I prefer to give them notes. I know that's traditional; write it on the board….*

In continuing to teach their classes separately, TT1 and TT2 were trying to maintain a sense of ownership of students and space which the new learning environment would not allow. As the two classes were seated in the centre of one large space, there was no *"defined line"* between them, even though teachers taught from opposite ends of the space.

> *TT2: I had to get my class quiet to listen, and his class was doing their work and talking, and then it was the same for him, I noticed that he would try to get his classes' attention and then my class is talking. But then it was like, who's actually* **in** *my class? Where's that defined line? Have I got everybody's attention (laughing)?*

**Demonstrations and practical work**

TT1 and CL both regarded practical work and demonstrations as important, not only for reinforcing science concepts but for engaging students and igniting interest in science. Part of the grief for what was lost in the transition to new spaces was the art of execution and class control from the position of 'science magician'.

> *CL: It was…a bit of a show, you know, especially being science, because you had the science kit, you had the demos, you could always…you know, set something up and fiddle with something… like quite often I had some quite good techniques to bring a class back in to talk to all of them and…. I guess control and lead a group of 30 students on a learning journey…*

> *CL: Often a practical, you'd set up or you'd figure out just before you do it, but you've lost that ability, and same with just randomly blowing stuff up. You can't just do things off the fly.*

> *TT1: I've got a lot of demonstrations and experiments in my head that won't come out until some student says something and I think, 'Oh yeah', I could show you that, but I can't do that anymore because I have to get the lab technician. It might be something simple, just static electricity on a plastic rod and how it bends water. Well, I'm not going to do that.*

Separating science teachers from their equipment and laboratories made it less achievable to include spontaneous demonstrations as part of incidental or impromptu learning during discussions and teaching sessions. The separation also made practical work more difficult because a higher level of pre-planning was required. The effect was less practical work overall.

> *CL: Over the first six months there was a huge drop in the amount of practicals that teachers were doing. Various reasons, not being able to set up before the lessons or tidy up afterwards, the logistics of not being in the same space as you're doing a practical while you're working made it for a lot of teachers into the too-hard basket.*

> *TT1: In the new environment I find myself doing less practical, because it is inconvenient or sometimes difficult…First of all, you've gotta book the lab and if someone else is in there you have to find another lab to book... Yeah, so you book the lab and you move in there, you do your whatever you're going to do and then you come back out…*

**A repositioning**

A desire to be 'good' teachers, and a sense of professional responsibility resulted in TT1 and TT2 finding new ways to work together. There was a shift away from teacher-led approaches to more independent, student-led learning, with students *"forced"* to do more for themselves. TT2 explained:

*TT2: The traditional way with your own room, you can teach more at the front…but then (students) get more reliant on you giving them the information. In the pods they're actually forced into doing more for themselves.*

The following paragraphs describe steps taken by teachers in the case-study school in this repositioning. The first was innovative use of digital technologies. TT1 was exploring 'flipping' the classroom. He had started to develop sets of online videos explaining science content, including revision questions for students to access in their own time, at home or at school, to enable them to learn at their own pace.

*TT1: I'm trying different things now because I have found also EdPuzzle where I've taken my videos and I put multi choice questions….*

Freed from the 'teacher-as-expert' position as deliverer of content knowledge in class time, TT1 found he was instead able to support individuals, tutorial style. However, TT1 found that developing the flipped classroom videos took time that he did not always have and that some topics required more *"teacher talk"* than others.

*TT1: Mechanics I've got a good set of videos, I'm developing a set for genetics…maybe eventually I'll get there, but it takes so much time. And chemistry is a difficult one… I think kids need more talking for that one…teacher-talk.*

As both teachers were doing less up-front teaching of content, printed workbooks were used as important resources which structured content learning for external assessments. Workbooks were also used to step students through research-based tasks for internal assessments. The workbooks supported students to work more independently through notes and questions. A shift to more 'guide on the side', facilitative teaching styles necessitated a second new initiative. As teachers visited individual students they kept track of progress by making a record of the learning conversation; where each student was up to and any next steps that were discussed. Teachers found this new initiative was necessary as students progressed at markedly different rates.

*TT1: Yeah that's a good thing that I've started with just a book to record…*

*TT2: Each of them are pretty much just working at their own pace but we've given them timelines of 'you need to be up to this page by this day', but some of them are 20 pages ahead.*

A shift to team teaching and collaborative styles was a third and major repositioning of practice for TT1 and TT2. In spite of CL's deliberate manoeuvres in timetabling the year 11 science classes together to facilitate team teaching, this did not happen at first. There were multiple factors affecting the teachers' ability to co-teach, such as the question of ownership of students (*"my class"*) and of the decision-making process.

*TT1: I don't know what it is. We just never collaborated (laughing). At first, I thought I would like collaboration, but in some ways, it's nice to do your own thing. It sounds very…what do I say? Against what they're trying to do.*

There were also practical considerations, for example, the time required for focussed and intentional co-planning. Co-teaching across junior and senior classes meant maintaining multiple collaborative relationships, which led to unworkable time demands.

*TT1: That's the problem with collaboration, you have to meet, and then the only time you can meet is if you've got a non-contact at the same time which is rare, so you've got to meet after school, or before school, and we find we've got so many meetings at school.*

Observations were conducted for the case study during term three (August 2016). During this time, TT1 and TT2 began team teaching for the first time. The practice of team teaching in a shared space with shared ownership of the two classes opened opportunities for students to choose the type of science learning they would engage in. While some students preferred to sit examinations for all three external science achievement standards at the end of the school year (a measure of the more academic students), some preferred to gain credits by working towards internally assessed standards. In the team teaching environment, each teacher offered a different level one NCEA achievement standard. Students could choose to work towards demonstrating their understanding of genetics ideas in an externally assessed biology standard or carry out a task-based internal earth science investigation. Each standard was worth four credits on the NCEA assessment framework (see Appendix A):

> AS90948 **Science 1.9:** Demonstrate understanding of biological ideas relating to genetic variation
> 4 credits External
>
> AS90955 **Science 1.16:** Investigate an astronomical or earth science event
> 4 credits Internal
>
> (NZQA, n.d.-e).

Students opting to do the earth science internal could choose between two different contexts. One was the 2011 Christchurch earthquake and the other was the 2011 Tōhoku earthquake and tsunami. TT1 explained that if students were given open choice of contexts, teachers would then need to *"research to find out if the student is giving you correct information"*. TT1 stated that this would make the marking process *"more difficult, more work"*.

In addition to offering learning choices to students, TT2 pointed out that there were advantages to team teaching, such as sharing the workload.

> *TT2: We're actually bouncing ideas off each other. (TT1)'s working with the people doing the internal, and I'm working with everybody doing the external, and so it's made it easier that way.*
>
> *TT2: I wouldn't try to do what we did in the first terms again because that was getting really difficult…yeah…we were exhausting ourselves, when we were both trying to get to the same goal.*

### *6.1.4 Interpretive discussion of school one case study*

This case study demonstrates that significant pedagogical and social adaptations were required when the teachers transitioned to flexible learning spaces. It confirms claims that teachers are challenged when they are called upon to adapt and respond to new physical teaching and learning environments (e.g. Alterator & Deed, 2013; Cleveland, 2016; Osborne, 2016; Saltmarsh et al., 2015). The science teachers in the case study school had no choice but to make a transition as their learning environment was rebuilt and transformed beneath them. They tried to continue at first as they had always done but found the new spaces would not so easily allow this. As suggested by Dovey and Fisher (2014), this 'forced repositioning' demonstrates that the physical reality in the form of classroom space that teachers inhabit is not always of their own choosing, and that conditions constructed within this new reality can act to constrain established practice or even to enforce new ways of being.

Teachers positioned themselves differently within discourses of 21st century and traditional learning by actively accepting or resisting the change in their circumstances. CL acknowledged that change was difficult but argued that there was a need to move on from the *"old system".* TT2 as a beginning teacher decided *"it was just something new again".* TT1 at first resisted, and then resigned himself to the change, realising that it was not the Principal but the Ministry who were *"pushing this".* TT1's experiences are comparable to those reported in the study by Benade (2015a), where for some teachers, changing meanings of being a teacher in FLS were associated with resistance and the perception of a loss of control.

Teachers in this case study felt that practical work and demonstrations were a fundamental part of assisting students to learn new science concepts and a way of keeping students interested and engaged in science. CL described a *"significant grieving period"* as staff reconciled new possibilities for being a science teacher in new spaces with the loss of ability to *"randomly blow stuff up"* using skills developed over 20 years, but which were now less relevant. At the time that the case study was conducted, other ways had not yet been found which would compensate for the lost identities of 'practical demonstrator' or 'science magician' which were the consequence of the separation of laboratory spaces from other teaching spaces. Neither were there answers at the time of the study which would address the issue of decline in the amount of practical work being conducted, which was another consequence of the separation of laboratory spaces from the main open teaching space. The literature I was able to access on teacher transition and adaptation to new learning spaces (see section 3.1) did not focus on issues such as these, which are specifically associated with science education.

Also evidenced in this case was the value that teachers placed on positions of science teacher-as-expert and transmitter of knowledge. This finding reiterates the predominance of these more traditional pedagogical approaches in science that have also been identified by others, for example Carlone et al. (2010) and Tytler (2007). Teachers in the case described NCEA level one external achievement standards as knowledge based. They were conscious of their duty to 'get students through' these assessments and saw teacher-centred pedagogies as the most efficient method for accomplishing this, in a manner similar to that described by Edwards (2017) and Spiller and Hipkins (2013) (see section 3.4.6).

Bisset (2014) suggests that it is possible, but difficult, to operate in a FLS in a very traditional way. Findings in this case suggest that in FLS, teachers were less able to experience themselves as 'good' science teachers who teach from the front, lead class discussions, and who help students remember and revise science concepts through the spontaneous use of quizzes or games. In accordance with issues identified by Lovejoy (2014), this was due to noise and distraction as teachers competed for attention of specific student groups within the open-plan environment.

Congruent with research by Melville and Bartley (2013) who noted that teacher identity can be understood as continuously reconstituted, findings suggest that the inhabiting of flexible spaces did catalyse some different pedagogical practice. Teachers were able to reposition themselves, finding new strengths as team teachers, collaborators and learning facilitators. Additionally, by accessing the affordances of digital technologies as digital pedagogues, teachers were able to maintain some traditional identities, albeit in a reconfigured way. One example was TT1's use of flipped learning. Lin and Bolstad (2010) observed that finding the time to develop and use digital technologies was an issue for teachers in NCEA assessment contexts. TT1 similarly commented that extra time was required to develop his flipped learning resources. However, this shift to digital pedagogies permitted TT1 to keep his teacher-as-expert position and enabled him to provide differentiated support for students in a revitalised, digital, space. This emergence of more student-centred teaching and learning approaches is in keeping with evidence of synergies between personalised learning and flexible spaces to be found in the literature (e.g. Bolstad & Gilbert, 2012; Cardno et al., 2017; Wright, 2017, and see section 3.1.2).

Overall the transition to flexible learning spaces in this school challenged and changed teachers' understandings and experiences of who and what a 'good teacher' is and does. Teachers were less able to adopt identities associated with 'traditional' teacher-as-expert and practical demonstrator which they had previously found to be effective for supporting students to achieve in NCEA science. The new spaces instead were compatible with and supported new identities of team teacher, collaborator, and facilitator of learning.

Section 6.2 presents data and findings from the second case study school.

## 6.2 School two case study: An enabling space

The theme in this second case study is the negotiation of what it means to be innovative 21st century teachers in a new school built as open, flexible, learning spaces. Data are presented to illustrate ways in which the inhabiting of this new 21st century space simultaneously enforced and enabled innovations associated with a shift to more personalised, student-directed approaches. Data also depict how teachers' thoughts of innovation and 'being innovative' sometimes conflicted with more traditional views of science teaching.

### *6.2.1 Contextual information*

**The school**

The case study involved the science learning area coordinator and two teachers of two year 11 mixed-ability classes in a mid-decile, mid-size (1200 students), co-educational, state secondary school (Ministry of Education, 2018d). The school was situated in a growth area on the outskirts of a large city. The school was built as a new build on a new site and designed as open, flexible spaces.

The school's purpose and intent, stated on the school website, was to offer a responsive curriculum and to develop students as 21st century learners. Inquiry learning philosophies including student choice and self-management were central to learning in junior secondary (years seven to ten). Another key philosophy was connected learning, where students were connected in their learning across curriculum areas, to other students, and to communities outside school. In the case study year, students studied separate NCEA courses in subjects such as science, English, or mathematics. Science at NCEA level one was compulsory for all students at this school.

**The learning space**

Four interconnected, dedicated laboratory spaces were situated at one end of a large, long, open learning commons. The four laboratories were arranged in an 'L' shape with floor-to-ceiling glass cavity sliders separating each space. This means that the spaces were flexible as they could be sectioned off or opened up to form larger spaces. Each space had a large fixed whiteboard but no data projector. There were tables and stools in the centre of each space. Along outside walls there were benches, sinks, and gas taps. Cupboards and shelves allowed for basic equipment storage. There was limited wall display space, although the glass dividers were used to display colourful student work and science posters. The glass sliding walls were also used as message boards, with notices and information written using removable markers. The technician's storage and preparation room was centrally situated, meaning all specialist equipment was easily accessible from all spaces.

### *6.2.2 Introducing case study teachers*

In September 2016 when the case study was conducted, two science teachers were team teaching two year 11 classes (about 55 students), although each teacher had pastoral and academic oversight for their own group. Three of the four interconnecting laboratory areas were available for the students and two teachers to use.

**Learning area coordinator**

The learning area coordinator (LAC) arrived at the school in its second year of operation to begin her first head of department (HoD) role, from what she described as a *"traditional environment".* The LAC underwent a significant readjustment and reorientation process as she adapted to teaching in a brand new, flexible learning environment, where there were *"no walls".*

> *I hit the ground running, literally in the interview, I had a thought of 'where the hell are the walls?!'*

*So…first year HoD…and a brand-new environment...I'd like to tell you that I came here knowing exactly what I got myself into, but I didn't…*

In her previous school, the LAC saw herself as an innovative teacher. Even so, it seemed as if the move to the new school enabled a 'stepping out of the box', and a degree of separation from the ways she used to practise. The LAC talked about having to re-learn how to teach.

*I'd been used to being one of the more innovative of the teachers at my last school, you know, with my PowerPoint and my activities, and pitch it at the middle, and have a lower level task and an extension task, and stand at the front, font of all knowledge…*

*(At the new school) It was basically…open the book...start again.*

She had to make a shift, yet up until the time of inhabiting the new environment, she practised only in terms of what she already knew.

*I guess you only know what you know, and when you come out of Teachers College and that's how you've been stepped through it by your Associates…you don't know any different.*

**Teacher one**

Teacher one (TT1) arrived at the school as a first-year teacher and was in her third year of teaching in the case study year. Previous teaching experience for TT1 was on practicum during her initial teacher education programme which was conducted in,

*…very much traditional labs, you know, notes on the board, that kind of thing, so it was great for giving me confidence but couldn't really translate a lot into this kind of environment.*

Although she stated that she had not been specifically prepared for teaching in flexible spaces, she felt able to adapt and translate skills she had learned, especially when she compared herself with more experienced teachers who she felt might be more established in their ways.

> *I'm at the start of my teaching process, and I came straight out of uni and so I was very prepared to be eager and enthusiastic and adaptable, and I've learnt all these things and so to come into somewhere like here wasn't a massive curveball for me. But I could imagine some people, who have come from a more traditional learning environment…it would be…*

**Teacher two**

Teacher two (TT2) came from a mid-size, mid-decile, co-ed school which operated in conventional, cellular classroom spaces. TT2 was in her second year at the school when I interviewed and observed her as part of the case study. TT2 was a very experienced teacher and had taught at secondary schools as well as at tertiary level. TT2 noted that at her old school there was a culture of working together, openness, and sharing of practice. She felt that her practice had not changed *"that much"*. However, with her reference point being her old school where classes were streamed, she did notice an adjustment to mixed ability teaching.

> *Now I'm having quite a lot of mixed ability classes – a sprinkle of the really good ones and quite a sprinkle of the really weak ones, and in one class.*

She also observed that students were given more freedom to move in the open spaces.

> *(In my old school) we do not allow students to pick and choose to come across physical spaces…*

As well, TT2 noticed differences in ownership of space and equipment. In her old school, *"chemistry was chemistry"*, whereas in her new environment, laboratory spaces were not designated, and specialist equipment was kept in a (central, accessible) storeroom.

> *Basically in (old school), this (room) was physics...and then chemistry was chemistry, so you have all the bio things, and all*

*the physics things…you have your own room and you have very thick walls because our (old) school is pretty old (laughs).*

### *6.2.3 What is innovation?*

**Innovative vs traditional**

Being in a brand new and state-of-the-art school, pressure was sometimes felt to 'be' innovative. One meaning for what it meant to be an innovative 21st century teacher was invoked in a move away from 'chalk and talk' or transmission-based teaching styles, moving instead towards more individualised, needs-based approaches. TT1 explained what she understood to be part of the learning philosophy of the school:

> *TT1: We are actually discouraged…without using that word, from the 'chalk and talk'. So, we are group learning, differentiated learning, individual, needs-based planning. So, I would be embarrassed, and feel like I had been naughty, if our Principal walked in and he caught me talking at the board.*

According to TT1, the Principal acknowledged that there was a *"time and a place"* for this type of transmission approach. All the same, she too disowned sage on the stage styles as largely ineffective for a group of learners with diverse needs, some of whom might be *"lost from the start".*

> *TT1: I stand at the board, but I'm very conscious, if I'm talking for more than 20 minutes, I'm either losing some people...or there are some people who are lost from the start, and the longer I go on, the less time I have to talk with them, so I try and keep it brief.*

Laboratory spaces were equipped with large whiteboards which did allow teachers to teach from the front using responsive, 'chalk and talk' styles, should they so choose. Yet it was noted earlier that there were no data projectors in the laboratory spaces. This meant that teachers were not able to support their transmission-based teaching with PowerPoint presentations. Teachers wanted to be able to choose for themselves how they could inhabit the space, without restriction.

*LAC: I've had this conversation with one of my new teachers who came from (another secondary school) where he had his own cell (classroom) with a projector, and he's struggled a lot with not having a projector on hand, and we had a lot of discussion about what 21st century learning is…*

TT1 and TT2 were in agreement that the drive to be innovative and to embrace 21st century styles should not mean denying teachers equipment which, while associated with 'old' transmission-based approaches, might otherwise be useful.

*TT2: To me, innovative doesn't mean something new, just because something is old doesn't mean it doesn't work.*

*TT1: We would love data projectors in here, we would love them.*

The LAC made the point that with the school opening at first only for years seven to nine students, newly employed staff had time to plan, to innovate, and adapt. There were two full years before the first year nine cohort moved to NCEA level one and national assessments commenced. During these early years, junior students worked in an integrated inquiry learning programme. The LAC described the contrast between inquiry learning in junior school, and what she described as *"traditional learning"* under NCEA. The LAC worried about the lack of specific scientific conceptual knowledge or *"base knowledge"* for junior students coming into level one science from an integrated inquiry focus in the junior school.

*LAC: They had very little science from year nine, the first year the school was open. They basically knew how to write up a scientific method, which is not helpful for NCEA. Anyone who knows inquiry knows that (scientific method) is a very similar format to setting up an inquiry, so our kids only were taught that, so they had very little base knowledge going into their NCEA year.*

Once students were in year 11 at NCEA level one, focussed teaching or *"frontloading"* of the knowledge required for external examination topics was the preferred method to ensure any gaps were covered. The quotes below show the power of the NCEA assessment frame as it impacted teachers' practice.

> *LAC: We tried to keep it a little more traditional, so we decided to do a term of biology, a term of chemistry, and a term of physics, so we'd start with frontloading of the external topic, and we would follow that up with an internal...*

For example, teachers would first frontload information for the knowledge-based acids and bases external achievement standard, where students were required to demonstrate understanding of chemistry concepts. They would follow this learning with an internal where students investigated the chemical properties of metals for use in society:

AS90944 **Science 1.5:** Demonstrate understanding of aspects of acids and bases
4 credits External

AS90946 **Science 1.7:** Investigate the implications of the properties of metals for their use in society
4 credits Internal

(NZQA, n.d.-e).

Teachers and the LAC were adamant that innovation should not be just for 'innovation's sake'. All three remarked upon the disconnect between expectations for innovation in teaching and learning and the need to prepare students for content-heavy external examinations which required students to memorise facts, vocabulary, and information.

> *LAC: Externals are...difficult, because...it's that format of them, it's an exam, you have to spew out information, you have to put the right key words in, you've got to know how to approach a question and things. So that's a little bit more tricky…so there's not a lot you can do that's really innovative there.*

> *TT1: Externals are tricky because there's so much memory involved and it's just such a different way of assessing understanding and learning. I mean, really, a lot of (externals) could just be assessing memory capability, or study capability.*

TT2 defended her need to engage in teacher-led revision at the whiteboard to prepare students for external examination topics.

> *TT2: If people need to do board work then do. OK?* ***Then you do it!!*** *(Emphasis). Because it's part of learning. And I don't do it for the whole lesson, but, if I have to…The other day I did it with the year 11s, some revising, the whole (external) topic.*

All three took a pragmatic approach to teaching and resourcing and relied on a variety of approaches to suit individual learners' needs. Teachers made use of digital learning platforms as well as workbooks. Students could choose which resources they wanted to work with and were not limited to one way or another.

> *LAC: We still do worksheets, we do practicals, all the things everyone else would do, it's not like we chucked everything out the window. And the kids can self-manage with their Scipads (workbooks), the Google Classrooms...*

**Innovative practice**

Teachers had capitalised on the flexibility of the learning spaces and the flexibility inherent in the modular matrix of NCEA achievement standards and were team teaching to support a variety of student choice. Teachers could close the glass sliders to minimise distractions caused by noise from other groups while they connected with their own class. In the same way, sliders could be opened to permit one teacher to address a larger group. Supervision of students across spaces was possible due to the visibility provided by the transparent walls. Teachers and students could move easily between and across spaces.

While content-based external standards seemed to attract frontloading and teacher-directed styles, internal achievement standards supported learning using more inquiry-based approaches. Teachers supported students to choose their learning depending upon their situation and encouraged students to:

> *TT1: …think about what they need, think about what their goals are, what's achievable…*

For example, within the discipline of physics, students could choose to work towards a practical internal standard supervised by one teacher, while the other teacher supervised students working on another physics internal standard in a variety of inquiry contexts. This was a departure from practice at the LAC's and TT2's previous schools where students completed the same achievement standard at the same time and within the same context.

> *LAC: My last school was traditional, everyone did the same thing for the research standard.*

> *TT2: Here we do give them quite a lot of choices, the students are used to making their own choices. In (old school) I would force everybody to do a practical, so 'Everybody does that!' (in a bossy voice). But here, we give them choices, voluntary…*

Team teaching also enabled TT1 and TT2 to appreciate their different strengths and to learn from each other.

> *TT1: (TT2) is so brilliant, and talented and extremely brainy. (TT2)'s got quite a different way of explaining and teaching some concepts to me. A lot of the students who are excelling really enjoy her kind of more complex...(explanations/teaching).*

> *TT2: The good thing is that (TT1) is really good at talking. Most of the common briefing is done by her and it is good for me because I get to learn off her, because of the different style in the teaching.*

Teachers' acts of innovation in the new environment included implementing simple changes which effected positive results. For example, observing and learning from others enabled the LAC to make shifts in her practice. She declared that she *"wouldn't go back"* to the way she used to practice.

> *LAC: Being in an environment like this and having a lot of primary trained teachers was the best, because I observed what they were doing, and picked up some things and tried some things and so being here allowed me to step out of that comfort zone and try new things, so I think I'm changed for the better as a teacher, from that difficult experience, and I wouldn't go back to the traditional way of doing things.*

Another example of simple innovation was that students sit at whiteboard tables. These could be written on with whiteboard markers and enabled teachers to workshop with groups of students. Going from group to group with a whiteboard pen, teachers were able to help students with particular issues in a very focussed way.

> *LAC: In my mind, I think a 21st century teacher is one that uses innovative practice, not just tools. So, sitting with a kid, in a group and writing on a table, doesn't sound fancy or innovative, but it's actually been the best way to do things...the kids feel safer, they can ask you questions, they're sitting with their friends, and they become the teacher as well, so you can leave a (whiteboard) pen with them, and they start teaching each other.*

**When to be innovative**

In the midst of expectations for change and innovation, the strength of traditional teaching practices was still apparent. When a Ministry of Education review agency visited the school, there were tensions between expectations for innovative styles and requirements for teachers to demonstrate capabilities within established practice. Lesson plans involving learning intentions and success criteria are traditionally used to structure learning sessions, but these can be associated with assumptions that students are working on the same material and progressing at roughly the same rate. These had less relevance in the flexible spaces where students were on more personalised paths. When being assessed by the agency, teachers were told by senior management to adhere to conventional systems; in effect presenting one view of teaching and learning while doing another.

> *LAC: It's difficult sometimes…like you're encouraged sometimes, especially when ERO are coming, to put your learning intentions and your success criteria on the board but…it's very difficult in the way we run our senior school…not every kid is at the same place anymore, some are back a couple of learning intentions, and some are ahead.*

### *6.2.4 Interpretive discussion of school two case study*

This case study provides further evidence that suggests that inhabiting new flexible spaces simultaneously enforced and enabled pedagogical innovations. The school philosophy of developing students as 21st century learners under a responsive and inquiry-based curriculum by implication entails teachers also developing as 21st century teachers.

As part of inhabiting the new spaces, senior science teachers were under pressure to move away from traditional teacher-centred approaches and to be ‘innovative’ in their new FLS environment. The three teachers in this case needed to negotiate meanings for what this might look like in practice. Deed, Lesko, and Lovejoy (2014) argue that the shift towards open learning spaces places pressure on teachers to adapt their conventional practice, and for teachers in the case study school, this pressure was not merely ‘felt’ or perceived. Pressure to innovate originated from various sources within school leadership and expectations of being a ‘new school’. This pressure is also in line with clear statements of expectation from the Ministry of Education that flexible spaces will enhance important social and pedagogical opportunities such as “encouraging collaboration and inquiry for both learners and teachers” (Ministry of Education, n.d.-c).

The lack of data projectors placed pressure on teachers to innovate by tacitly communicating that traditional teacher-transmission styles were not anticipated in the new learning spaces (section 6.2.3). However, the teachers in the case study wanted to be free to practise as they wished, and for old and new ways to co-exist. Issues of material resourcing in flexible spaces such as this are not specific to science teaching and learning, but somewhat surprisingly they were not highlighted in the literature I was able to access as part of this study.

All three teachers aligned themselves with 21st century ideals of collaborative inquiry teaching and learning, explaining that *“we are group learning, inquiry learning”.* Yet similar to teachers in case study one, teachers in this case also found transmission styles to be effective for ‘getting students through’ external NCEA knowledge-based assessments. This meant that although the school’s inquiry learning philosophy was well established in practice at the level of junior science, the case study teachers signalled that it was more challenging to put this fully into practice at senior level.

Leiringer and Cardellino (2011) point out that teacher transitions to rebuilt flexible spaces are different from teacher transition to new builds. They argue that in a new school, teachers 'opt in' by applying for a teaching role, and as such could be more likely to possess both the inclination and ability to adapt. With respect to constructionist theorising, it could be said that once teachers have chosen to take up new roles, they then position themselves in terms of the storylines associated with those new roles. Teachers then 'see' that world from their new vantage point, and therefore are more able to construct appropriate identities for 'good' teachers associated with the new context (Davies & Harré, 1999; Edley, 2001; Hall, 2001; Søreide, 2006). This reasoning would seem to apply to the teachers in school two.

Compared with the teachers in school one, the shift to new teaching and learning spaces for teachers in school two whilst sometimes challenging, did not seem to be associated with the same feelings of grief or lost identity. TT1 did not perceive her transition to be a *"massive curveball".* For TT2 and the LAC who were both experienced teachers, the repositioning happened as they began their new roles in newly-built learning spaces, and this appeared to enable a degree of separation from their old and perhaps more traditional ways. As the LAC related, *"it was basically...open the book and start again".*

A second possible factor influential in a smoother transition for school two teachers when compared with school one, was that teachers in school two had time to adapt to and to experiment with 'being innovative' and with using inquiry learning strategies at junior level, without the pressure that NCEA assessment brings. This was because the new school opened at first only for junior students, with senior year groups added as students moved through. Innovation for the teachers in this school involved seemingly straightforward and practical undertakings, such as observing and emulating another teacher's practice or writing on a whiteboard table (section 6.2.3). The LAC also explained that teachers *"had a lot of discussion about what 21st century learning is".* It was possible that as a new school, teachers had more time and space for discussion, observation, and reflection. This finding confirms Campbell et al. (2013) and

Osborne's (2013) claim that open, flexible spaces contribute to de-privatisation of practice and offer opportunities for observation of and reflection on different pedagogical approaches.

A third factor in enabling the shift for teachers was the design of the agile physical spaces themselves. Agility is a feature of flexible spaces as described by Dovey and Fisher (2014). Sliding glass walls meant that it was easier to reconfigure the space to offer students choices in where, how, and with whom, they learned. The agility of the physical spaces in this case study school allowed areas to be sectioned off into more traditional cellular classroom arrangements. The spaces were also enabling for practical work, as all four science areas had easy access to equipment. Dedicated practical areas were integral to, rather than separated from, the science learning areas and larger commons.

Overall, the navigation of what it means to be innovative 21st century teachers in flexible spaces changed who and what a 'science teacher' was and did, as certain possibilities for action were enabled and constrained. In some ways, teachers in this case study school were under pressure to take on new identities as a consequence of them choosing to teach in a newly-built school. However, in some ways their transition was eased. Teachers opted in to their new roles, and they had time to adapt to teaching and learning in flexible, and enabling, science spaces.

The next section introduces the third case study school.

## 6.3 School three case study: A future focus

A key theme highlighted in the third case study is the way that the new science spaces accommodated existing and conventional approaches to science teaching for one teacher, while simultaneously supporting other, more innovative approaches. Data depict how the new spaces were a catalyst for the development of a future-focussed vision for student-led, personalised learning in a technology-rich environment.

### *6.3.1 Contextual information*

**The school**

The case study involved the science head of department (HoD) and one teacher of a small year 11 mixed-ability class (19 students) of science learners in a small (500 students), low decile, co-educational, state secondary school (Ministry of

Education, 2018d) in a small North Island town. This school was a newly built campus and catered for years seven to 13.

The school philosophy was focussed on developing an inclusive school culture and on using innovative approaches to raise achievement across all subjects for all learners. Learning was contextualised by focussing on local geographical features and major industries which provided employment in the area. The small size of the school meant that senior leadership needed to be innovative in their efforts to enable a small number of staff to cover a large variety of subject options. Exploiting the affordances of digital technologies was part of the solution. Many classes were run as multi-level learning hubs across two or three year-levels, and the school accessed a virtual learning network to offer some senior courses. There were no course entry restrictions in any subject. In the case study year, level one science was optional, and students could change options every term, so students would appear and disappear from science classes on a term by term basis.

**The learning space**

Science sessions were conducted in a separate closed-off space, although it was not a 'classroom' in the four-walled, cellular sense. The hexagonal-shaped space was more open to other internal spaces and to the outside than a conventional classroom. The space had three tiers of stadium-type seating built in across three back walls. Of the other three walls; one opened to the careers room through a glass slider. One wall was taken up with a whiteboard and data projector screen, and on either side of these were two separate openings to other larger commons. The final wall was made of glass sliders which opened to an outside area where there were tables and seating. The enclosed learning space was not immediately adjacent to the shared laboratory space, although the laboratory was close by and accessed from the large commons area in the same building.

The laboratory was set up as a rectangular space with tables in the centre and practical stations down the two long walls of the rectangle. Specialist equipment was stored in a side room. Both short walls of the rectangle opened through glass doors onto two different commons, and this openness gave the impression of the lab being like a very large galley kitchen. The commons areas were made up of a combination of many carefully apportioned spaces which enabled different learning configurations. As well as large open spaces and small enclosed, breakout or ‘campfire’ spaces, a darker, narrow corridor accommodated desktop computers.

### *6.3.2 Introducing case study teachers*

**Head of department**

The science head of department (HoD) was also deputy principal in this small school. He came to the new school during the building process from a large co-educational state school where he had taught for ten years. He saw his role as a teacher differently in this new school, with less traditional content delivery and more small group support.

> *There's a lot less of your traditional teacher, with your direct instruction and standing at the front. There's a lot more student choice in what they do and when they do it. So it's more group facilitation and more monitoring, individual feedback, than traditional standing there and deliver. Your role is almost exclusively talking to small groups and individuals.*

The HoD was heavily involved in programme design and in leading the school-wide technology and digital learning initiatives. He associated the shift in role with the affordances that digital technologies and pedagogies provide. Digital devices can deliver information, which in the HoD’s view obviated the need for the teacher to do the same.

> *You can’t as a teacher now, deliver information. There’s no point, cos students can get that information at the push of a button. So, if you’re trying to deliver information, you’re fighting with the students and you’re fighting with technology…it’s not your role anymore. There is maybe a role for curation of information, but not… (content delivery).*

**Teacher one**

Teacher one (TT1) was an experienced chemistry and biology specialist of 25 years. When observed and interviewed for the case study, she was in her first year at the school, coming from 14 years at a medium-sized girls’ state secondary school, where she taught in traditional, cellular, laboratory classrooms. At the time of application for the science teacher position in the new school, TT1 had little idea of what *"modern learning"* environments entailed.

> *I'd heard a lot about modern learning, and didn't exactly know what it entailed, and when I came for the interview I was...I was surprised – 'Oh it's just a huge block! No walls…'*

TT1 liked the idea that the new reality without walls came with support for behaviour management.

> *The person who was showing me (around) said 'you'll have support' and so that actually encouraged me, because if there is somebody playing up I can always get team teachers...that was one very relieving thought.*

TT1 was proud of the fact that she had attracted students into science as an optional subject and gained satisfaction from seeing students enjoy and achieve in science.

> *They have really got into science and a lot of them are saying we will take science next year, cos in year 11, science is optional.*

### *6.3.3 The same, but different*

**The same**

TT1 claimed that she did not feel any different as a teacher in the new school and felt she did not practice differently. TT1 chose to conduct sessions in the separate, hexagonal-shaped classroom, complete with data projector.

> *TT1: (The classroom) has been my space because of…I love using the data projector.*

She did not lament the loss of practical laboratory space, rather, she saw advantages, such as not having to worry about clean-ups or about students touching equipment which might be off-limits.

> *TT1: (In the shared laboratory space) They touch things they're not supposed to, and you are worried about the cleanliness of the lab.*

In TT1’s science class, students worked as a group towards single achievement standards in a single context. In term three 2016 when the case study was conducted, students were working on an internal achievement standard which involved a practical investigation. The context chosen by the teacher for the whole class was “the effect of exercise on heart rate”.

> AS90925 **Biology 1.1:** Carry out a practical investigation in a biological context, with direction
> 4 credits Internal
> (NZQA, n.d.-e).

The HoD’s impression was that teaching and learning in TT1’s class was more aligned with traditional whole-class approaches than with allowing individual student choice.

> *HoD: I think there's more whole class traditional teaching with a bit more student choice, but that student choice would be whole-class student choice, you know, which of these standards would you (as a class) like to do…*

The HoD’s ideas that learning should be more self-directed differed from TT1’s views that learning should be a teacher-led, collective process where students progress together and help each other.

> *TT1: Right now, with my year 11s, I'm trying to keep them the same, together, because otherwise, once you give them the liberty, each one will lose track.*

> *TT1: They progress with their peers, and they ask their peers, and they take help and each one helps out each other, but if each one was doing their own stuff, they get into a cocoon.*

**But different**

While the teacher did not see herself as practising differently, students were permitted to make use of the flexible spaces by choosing where they worked, within limits. Once initial briefing or teaching episodes were over, students were free to move and chose to sit in groups on the tiered seating, at the tables outside, in the commons next door, or on couches in the adjacent careers room.

*TT1: Once I give them the work, they are free to go anywhere. They go anywhere as long as they are doing the work. I should have a sight of them, where they are, so that I can go and check what they are doing. They can't wander off.*

Digital learning was a feature in the school. Students used Chromebooks in a dedicated 1-to-1 digital environment. Google Classrooms was used as an online learning platform where students could post work and teachers were able to comment, as well as a repository where notices, tasks, resources, and assignment due-dates were posted for each subject. Printed workbooks were not used at all for science learning.

*HoD: All students have access to a Chromebook. All courses have a Google site and a Google Classroom. We're also moving towards each course having a Blog as well. So students can access any of the learning, any of the time.*

TT1 acknowledged that digital technologies enabled students to access their learning at any time or place, and that this was an important part of the school culture and learning philosophy.

*TT1: The main thing in this modern learning is, you must encourage any place, anytime, anywhere. That's what it is.*

Nonetheless, TT1 was focussed on her duty to get students through *"fact-based, concept-based"* science assessments, especially for external examination-based standards.

*TT1: Our whole job is to prepare students for NCEA assessments. Unfortunately, NCEA is so assessment driven, so we have to prepare them for an assessment.*

*TT1: (The externals are) very content heavy, and it's very, you know, fact-based, concept-based. Unfortunately, that's the nature of science.*

She felt that learning solely with digital devices in an online environment was not necessarily the most effective means of helping students to achieve, as they were sometimes distracted by other online attractions.

> *TT1: That's one disadvantage of modern technology, you see, the moment they have a Chromebook, quite a few of them get distracted by other websites. Facebook is too interesting... (laughing). Why would I do (work) when there's interesting Facebook and YouTube?*

TT1 had used science workbooks in her old school and saw these as important resources for presenting organised (distraction-free) content and questions which support and scaffold students' learning.

> *TT1: I love those workbooks. I've told (HoD) that we need some workbooks.*

**A future focus**

TT1's views on digital learning and student-directed learning contrasted with those of the technologically-savvy HoD. The HoD acknowledged that the shift in roles to more student-centred and digital learning not only pertained to the students, but that time was needed for staff to make the shift.

> *HoD: The staff need training and support and scaffolding.*

The HoD explained that although *"we've let (TT1) run with a more traditional program",* the senior leadership team had a different end-goal in mind and had expectations that school-wide learning would move towards more individualised, student-centred programmes and team teaching approaches.

> *HoD: This year we are not where we want to be and where we will be next year. (This year) the use of the learning spaces is towards the traditional…*

> *HoD: What we want is a team teaching approach where we focus on student choice, and, pushing the key competencies, you know, self-management, relating to others. So, what we're doing*

*is…we are designing the curriculum with students at the centre but also spaces at the centre as well.*

*HoD: So, a large amount of student choice. You're shifting the focus away from…you don't deliver a course anymore, but the focus is on monitoring students and facilitating.*

### 6.3.4 Interpretive discussion of school three case study

Led by senior management, the future focussed 21st century vision for this small school privileged digital pedagogies and student-directed approaches implemented through student choice, with the overall aim of catering for diversity and raising achievement. This case study has illustrated how the arrangement of flexible spaces simultaneously supported different possibilities for practice and different teacher-identities.

The HoD was strongly aligned with the new direction for learning. According to the HoD, learning was most effective when students were given choices in their learning. To him, technology was the teacher and thus teachers' roles were changing. He constructed teachers as 'information curators' and 'facilitators' rather than information deliverers. His positioning is in line with Ministry expectations for affordances of digital learning (Ministry of Education, n.d.-b) and with others (e.g. Bergmann & Sams, 2014; OECD, 2013; Ruano-Borbalan, 2006) who maintain that digital technologies have the potential to disrupt or dislodge the teacher from their conventional teacher-as-expert positions. While others have highlighted issues associated with the time needed to learn, adapt to, and use new digital formats (Hilton & Hilton, 2013; Lin & Bolstad, 2010), interestingly, this was not mentioned personally as an issue for the HoD. However, he accepted that time was needed to support other teachers in these aspects.

TT1 who had arrived at the school at the beginning of the case study year, positioned herself with respect to the teaching and learning of science in ways which were different to the HoD. TT1 described her practice as unchanged from her last school and was similarly positioned by the HoD as a *"more traditional"* teacher. TT1's experience of science as a *"fact-based, concept-based"* subject meant that she preferred teacher-led approaches because she saw these as most effective for supporting student achievement. TT1 sometimes permitted students to use the flexible spaces and choose (within limits) *where* they would learn. However, in terms of the grain size of context personalisation as defined by Walkington and Bernacki (2018), TT1 allowed choice at class rather than individual or group level, structuring *what* the class were learning as a collective, so that they didn't *"lose track".*

TT1 questioned whether the use of digital pedagogies and digital devices such as Chromebooks would help students 'get through' NCEA assessments. Instead, TT1 was focussed on helping her students to achieve in ways she thought best. While she was compelled to use digital pedagogies, she wanted the extra support for students that she felt printed workbooks could provide. This resembles findings in other studies where being a digital pedagogue was seen as being incompatible with, or less efficient than, more traditional teaching and learning approaches in high stakes assessment environments (e.g. Bisset, 2014; Hilton & Hilton, 2013; Lin & Bolstad, 2010).

TT1 was aware of the HoD's expectation that she would become a different type of teacher in time. She was in the process of renegotiating her approaches to science teaching and learning and her use of digital technologies and flexible classroom spaces. She acknowledged that in 21st century environments, learning could be different, yet her description of *"this modern learning"* indicated perhaps that she had not fully owned the idea herself. Other researchers have recorded teacher feelings of uncertainty and reluctance to move away from familiar, teacher-led approaches in reform environments (Danielsson & Warwick, 2014; Levinsson et al., 2013; Saka, 2013). The arrangement and resourcing of learning spaces in this school supported TT1 to continue as she always had by supplying her with an enclosed classroom area and data projector. TT1 was being given time to adapt by senior management, and in the case study year was not asked to team teach across year groups or subjects and was not expected to engage in more student-directed approaches.

Interestingly and in contrast to school one, the design and placement of the laboratory as a separate space in this case study was not an issue for TT1 or the HoD. TT1 enjoyed the separation from a teacher-control aspect, and the HoD found it possible to work in with others as needed. One possible reason for this difference could be the very small size of the school, as demand for and negotiation of the use of space may have been less complicated.

Overall, the design of the new learning spaces constructed conditions which permitted TT1 to maintain her habitual and more traditional science-teacher identity. At the same time, for the HoD, the new spaces were a catalyst for being a different type of teacher and he envisaged a more student-directed, digital learning future. TT1 was under the expectation that she would eventually makes shifts in her practice to more align with this vision.

Section 6.4 summarises findings and highlights cross-case themes across the three case studies.

## 6.4 Summary of three case studies

In school one key findings were: Teachers were transitioning to rebuilt open learning spaces. In the new spaces some preferred ways of being a ‘good science teacher’ were no longer possible or relevant. For the experienced teachers this transition was associated with a sense of grief. The separation of science practical areas from the main commons space and the inhabiting of open, shared space made it more difficult to teach as individual teachers using teacher-led transmission approaches. It was more difficult to conduct class discussions, games, practical work and spontaneous practical demonstrations. It was possible to team teach and to use student-led approaches. Associated teacher identities in the new spaces included team teachers and collaborators, learning facilitators, and digital pedagogues.

In school two key findings were: The agility of the science areas in this new school meant it was possible to reconfigure spaces to enable teacher-led transmission approaches or to enable team teaching and offer different learning choices. Teachers were under pressure to ‘be’ innovative in their new environments. Teachers chose to enter the new environment and actively positioned themselves as innovative 21$^{st}$ century teachers. Meanings for being ‘innovative’ needed to be negotiated within possibilities provided by space and resourcing. Teachers had time to adapt to new spaces. Teacher identities were associated with facilitating small group learning, team teaching and collaboration, and inquiry learning to support student choice. These approaches were sometimes in tension with transmission-based approaches preferred for external NCEA assessments.

In school three key findings were: The HoD was troubling the status quo with a future focussed vision for technology-based, student-led learning in this new FLS school. Identities were associated with being a learning facilitator, a digital pedagogue, and a curator of online information. On the other hand, the science teacher was continuing with the teacher-directed approaches she felt were most effective in ensuring students achieved in NCEA. The design and resourcing of the learning spaces permitted these approaches. Identities for this teacher were associated with traditional teacher transmission and leading student learning at the whole-class level. The teacher was expected to make shifts in her practice towards student-centred teaching and learning styles.

The overarching research question asks how the discourse of 21st century learning is shaping science education in terms of possibilities for teacher and student identities. In all three schools there was tension between traditional science teacher identities associated with 'getting students through' knowledge-based external assessments, and identities associated with collaborative team teaching and more personalised, student-directed science learning.

The phase one sub-question asks what science teaching and learning looks like. If the best, worst, most salient features from the three case studies were combined to produce a picture of NCEA science teaching and learning in FLS, what would it look like? Section 6.5 employs the technique of portraiture to illustrate this.

## 6.5 Portraiture

### *6.5.1 Introduction*

During phase one research I noticed that each of the three case study schools, as cutting-edge modern learning spaces, attracted many visitors who were curious to see the new spaces in action. For example, school three welcomed three separate delegations in one week. I was observing at school two when teaching staff from the entire science department of a large secondary school arrived. The visitors' own school was undergoing a complete rebuild, and the group had travelled for three hours to see the science spaces and talk with teachers at school two. I talked with a few of these visitors. I observed them as they walked around with bewildered expressions which seemed to me to say: “What’s going to happen to ‘us’ as a school? What will it be like for me teaching in new spaces? *How* will I teach?”

These sentiments echoed those of TT1 from school one. When speaking of the difficult transition time he remarked, *“we looked for information but couldn’t find it”.* TT1 was looking for answers about how to teach in new learning spaces and was trying hard to respond to new expectations for better learning. He told me: *“I don't find anybody telling me or giving me good ideas. I want to know, what can I do in my class to make learning better?”*

It was at this point that I began to form a response to these questions in the form of a literal answer to what does (or what *might)* learning look like?’

I constructed a portrait (see section 5.1.2) of science learning as a chronological narrative, arranged over a time slot equivalent to one teaching block (90 minutes). Each of the four elements are featured. Subheadings for each of the separate scenes depicted within the portrait highlight specific themes and categories associated with these four elements. The session is intended to show teachers and students working in flexible spaces, using digital tools, within the science curriculum, being assessed by NCEA. The portrait was constructed to minimise tensions between traditional and 21$^{st}$ century demands and to foreground approaches to personalised learning, while at the same time highlighting possible issues.

### *6.5.2 Structure of the portrait*

First, the school context and science learning spaces are described. Characters representing teachers and students are introduced. Next, the narrative of the session begins. In the session, two teachers work together with two classes to revise content for level one external examinations and facilitate learning for level one internal assessments. As the session begins, each teacher conducts a revision activity with their own class in their own separate areas. Then students transition to work on a choice of three different internal physics achievement standards. A practical investigation internal is overseen by one teacher. The second teacher works with a small group on an internal that introduces concepts needed for level two physics. The remaining students work individually on an internal physics research standard. Later in the session, both teachers run invitational revision workshops on externally examined topics in biology and chemistry. The session ends with students back in their separate areas with their individual teachers.

### *6.5.3 Characters and context*

**The (fictional) school context**

The school is a mid-decile, mid-size, coeducational secondary school in urban New Zealand, catering for students from years seven to 13. The school is a new build and has been open for five years.

Science learning at NCEA level one is compulsory in this school. The timetable allows for three blocks of 100 minutes of science every six days. Student autonomy and choice are key philosophies in the school, meaning students are given many opportunities to lead their own learning.

**The (fictional) learning space**

Science class is conducted in two adjoining laboratory spaces which are adjacent to a larger commons space and to a small room which stores specialist science equipment. The two laboratory spaces can be divided from the commons and from each other by floor-to-ceiling glass sliders. Students are grouped at whiteboard tables arranged in the centre of each space. Each area is equipped with a large whiteboard and data projector. Across the back wall, both laboratory spaces open onto the same shared breakout space which seats about eight to ten students. Benches and sinks used for practical work run along the two outside walls in each laboratory.

**Introducing (fictional) characters**

**Teachers**

Two teachers share two, year 11 science classes in the space described above. Teacher A (TA) came to the school as a newly graduated teacher and is now in her third year at the school. Her subject specialty is senior biology. Teacher B (TB) is an experienced teacher and has been teaching in the school since it opened five years ago. She came from a large secondary school where she had been teaching in her own cellular laboratory for 20 years. Her senior subject specialty is physics.

**Students**

Most students (SA, SB, SC…) have been at the school since its early years of opening. The year 11 science group numbers 52 students. Although TA and TB team teach this large group, each teacher is responsible for their own group when keeping track of progress and reporting to parents. At year 11, students are 15 or 16 years old.

Classes are not streamed. Instead, students work and learn in mixed-ability classes. Some students will go on to study one or more science disciplines at NCEA levels two and three in years 12 and 13. Many will complete some or all of the three level one external standards. Others will choose a different path and will gain credits in science mainly via achievement in internal standards. Upon leaving school, some students will to go to university and some will find an apprenticeship or employment.

### *6.5.4 A portrait of science learning*

The science session is timetabled after lunch from 1.35pm to 3.20pm. It is half-way through term three and mock examinations are scheduled for the last week of the term. One focus for the session is revision for the three external examination standards in disciplines of chemistry (acids and bases), biology (genetics), and physics (mechanics). Students are also beginning to work towards an assortment of internal physics-based achievement standards.

#### 1.30pm Space and time: Planning to work together

The glass slider is fully open, merging the two spaces into one. TA has prepared revision questions for the physics (mechanics) external examination standard as a starter activity. The questions are written on the whiteboard in TA's half of the space.

> AS90940 **Science 1.1:** Demonstrate understanding of aspects of mechanics
>
> 4 credits External
>
> (NZQA, n.d.-e).

TB quickly copies TA's questions onto her own whiteboard and then they stand conferring between the two spaces. Time for shared planning is limited, so they make the most of what they have.

> *Researcher (R) to TB: How do you decide what's going to happen each lesson?*

*TB: Sometimes when we are busy I'll drop things off at TTA's table to see whether she wants to use it or not. So we share our resources. If she has extras then we just share those, and then we email each other…so pretty informal....*

TA explains that team teaching is not always easy, and that it involves much give and take.

*TA to R: You have to have really good collegial relationships, so you have to be willing to work on those and actually work with other people and not be in your own little bubble cos the little bubble thing doesn't really work here.*

But she enjoys the feeling of support and camaraderie.

*TA to R: There's that solidarity within the last ten minutes of a Friday afternoon, when you can look at each other and roll your eyes.*

**1.35pm Class begins**

Class is about to begin. Music plays to signal the end of the lunch-break, and students have until the song ends to be in class. I stand and watch as students filter in while Pharrell William's *Happy* plays over the loudspeakers. TB slides the door to divide the spaces but leaves a small opening of about one metre. Each teacher is standing in their own space, greeting students and chatting with them as they settle. In this team teaching environment where students constantly move between teachers, one way of maintaining relationship and fostering a sense of class identity is with this established routine of beginning and ending sessions as separate groups.

**1.40pm Assessment: External examination revision via the teacher as sage on the stage**

Class is underway. Students copy down and answer the revision questions before teachers work through answers on their separate whiteboards with their separate groups.

*TA to her group: OK everyone, let's go through these answers. It's always good to revisit with repetition – it locks in into your* *long-term memory so you can use it when the exam comes around.*

This part of the session will be the only time that teachers act as a sage on the stage to their whole class. Students are expected to participate by listening and contributing. As individual students assess their understanding of the material covered, this revision session may play a part in informing their later decision to attend a workshop or to pick up an extra homework sheet.

**1.46pm Space: Noise and distractibility**

The teacher-led revision sessions continue. Sitting at the back of TA's space, I am conscious of noise. Both teachers can be heard talking to their separate classes. There are a few students in each area having quiet conversations which run underneath the teachers' voices; not too distracting, but nevertheless there. TB scoots over and slides the door fully shut. The noise goes away.

> *TB to R: When I feel it's noisy sometimes...I didn't realise that sometimes my class was not that noisy, but the noise was coming from other spaces.*
>
> *R: So you hear noise from other spaces…*
>
> *TB: So once I do (hear noise), I start to talk a bit louder, and then you will realise, because someone will come and slide the door (laughing). So it's good that's it's flexible.*

Although the two groups of students are visible to each other through the glass, there is little interaction between the two. This surprised me at first, until one day sitting in class I realised that although there was movement and activity visible through the glass dividers, I also had 'turned in' and was paying attention only to what was happening in the area I was in.

> *SC to R: You just forget about everyone else around you, in all the other classrooms, and then it's like normal. All the distractions are gone, kind of, cos you're used to it.*
>
> *SG to R: When you first get to this school it might be a bit overwhelming, but the longer you stay at our school it's quite easy, cos you get used to it.*

**1.50pm Curriculum: Learning choices in action. Assessment: Possible pathways within NCEA**

The revision sessions come to an end. TA checks that TB is ready, then the slider is opened. TA sits on a stool in the space between the two classes, so all can see and hear. TA addresses both classes to remind students of options for three internal physics achievement standards. One option is research-based where students are required to provide an account of the physics related to a chosen application:

> AS90936 **Physics 1.2:** Demonstrate understanding of the physics of an application
> 2 credits Internal
> (NZQA, n.d.-e).

Students can choose an aspect that interests them. They are able to integrate knowledge and contextual understanding from other curriculum areas such as physical education.

> *TA to R: A lot of our sports kids enjoy that one. In the past they've done CrossFit, so they look at a couple of movements of CrossFit and explain the physics to do with it.*

Another option is a practical investigation where students investigate the suitability of different materials as insulators.

> AS90943 **Science 1.4:** Investigate implications of heat for everyday life
> 4 credits Internal
> (NZQA, n.d.-e).

> *TB to R: This can be done as a practical, and we've had kids do insulation for homes, so we have a whole lot of Pink Batts and building paper and all sorts.*

The third option is for students who are wanting to take physics at level two. One of the goals of level one science is as preparation for specialist science disciplines in levels two and three. Electricity is an important topic in level two and three physics.

AS90941 **Science 1.2:** Investigate implications of electricity and magnetism for everyday life

4 credits Internal

(NZQA, n.d.-e).

*TB to R: (by offering this standard) they can have a little bit more of a head start for their specialist subject.*

Students may choose to complete one or more of the internal standards on offer, although teachers often have a say in guiding students towards choices which might be appropriate.

*TA to R: We do guide some students as to what choices they need to make. Some students aren't quite ready to make or have that responsibility…*

TA continues to explain happenings for the session. For most of the time students will focus on their chosen internal. This means that some students will work with TA in her lab to carry out practical work for the heat investigation. Some will gather in TB's area to work with her for the electricity standard. Some will collect a laptop and work independently on the physics of an application standard, either in the breakout room or at a free table in one of the labs.

Just before TA releases the students to begin work, she signals that two separate workshops will run in the final 20 minutes of the session as further revision for the mock examinations.

*TA to whole group: Also today, we've got some options for revision. You don't have to take these up - if you're studying at home, and that's enough study for you, and you've got a good plan, then use this time on your internals. (TB)'s got some chemistry stuff prepped, and I thought I could go through some biology. So, it's a massive task for you guys to manage how you're going to spend your time, and you can't afford to just sit around and just chat, at this point, cos there's too much to do.*

**1.54pm Curriculum: Learning choices in action. Space: What and where to learn?**
Students are organising themselves and moving to where they need to be according to the learning choice they have made. Nineteen students follow TA into her laboratory area to work on the heat practical. Ten students cluster around the data projector screen in TB's area to learn more about electricity and magnetism. The rest are working independently. Some remain seated at their tables while others move off to the breakout room. Some choose to work in the third, and empty, adjacent science area. There is a relaxed feel as students move and settle.

I talk with students about what they have chosen to do. They have been provided with a list of context choices for the physics of an application internal and for the heat practical investigation.

> *R to SA: So I just listened to your teacher tell you all about the options for your learning. Can you tell me a little bit about what you're thinking, about what you might do for these next few weeks?*
>
> *SA: Ahhh...I'm doing the heat practical internal, because it's a practical, it's easier for me.*
>
> *R to SB: What are you working on at the moment in your science learning?*
>
> *SB: The physics of mountain biking.*
>
> *R: How did you make that choice?*
>
> *SB: ...um...it was on the sheet, I just chose one.*
>
> *R to SZ: So you're doing the physics of skydiving. How did you make that choice?*
>
> *SZ: Skydiving looks easiest…*
>
> *R to SE: How do you make decisions about what internals to do?*

*SE: Um...mainly based on the credits, so I can get more credits…*

*R to SC: Do you mind telling me a little bit about what you're learning at the moment, in science?*

*SC: Ah, yeah, so we're doing an internal at the moment. We have to pick an application for physics, and then we have to kind of...describe it and show how it uses physics. So I'm going to be using a karate punch and talking about karate, cos I do karate, and I can talk about the physics involved with doing karate, and then hopefully get some credits.*

**2.01pm Digital or not: Learning choices in action: How to learn?**

Along with choosing what they will learn, students can choose how they learn. They are not limited to either workbook or digital formats. Positioned as independent and self-directed, students need to know how they learn best.

*R to SA: I see you are using your (workbook). Do you use a computer much for your learning?*

*SA: No. Computers don't help me at all.*

*R: Can you tell me more about that?*

*SA: I'm more a person, like, you write it down, in colourful colours, it reminds me better than looking at a screen. I just kind of, copy stuff in it, just write it down, and in words that I understand.*

*R to SF: How do you use computers for learning - or do you?*

*SF: Um, computers, it's just easy, like accessing websites and all that, that have more information than the teacher does. And just easier, learning, writing notes, and you can read, instead of her having to teach me stuff that I can figure out myself. Yeah, and writing down assessments, and handing them in, and just sharing (teachers) into my documents, so, if I need help, she'll tell me straight away on the computer.*

*R to SB: How do you learn in science, mainly?*

*SB to R: You get a (workbook) and you do certain pages…(…)… then you ask questions with the teacher, or you can ask your peers...you know, if they understand it.*

*R to SC: How do you learn best when you're doing science?*

*SC: Probably when I'm on my own, like individual, but also the workshops. It helps if the teachers come around and can write on the tables.*

**2.05pm Space: Learning choices in action: With whom to learn?**

Students appreciate having more than one teacher to work with because they are more able to access the help they need, when they need it.

*R to SM: Can you talk to me a little bit about how it is, working in this environment?*

*SM: It's good… having two teachers specifically here that teach science is quite helpful because, if one of them are busy helping another student, I can still have my hand up and the chance is the other one will notice. So it's easier to get help if you need it.*

*R to SJ: What do you think about learning in these spaces?*

*SJ: I think it's a good idea for science because if you don't understand one teacher's way of learning, you can go to the other.*

**2.12pm Space: Learning choices in action: Where and how to learn**

The electricity group is underway. Students are listening and taking notes as TB stands at the projector screen and talks through her PowerPoint slides. In TA's laboratory, students carry out their experiments and record results for their heat practical. TA moves around supervising the groups.

Other students have their laptops open, working on the physics of an application internal. I talk to two students who are working independently on this internal. SF is sitting on his own, at an empty table in TB's lab. He has headphones on, playing music. Standing beside him, I can hear the beat.

> *R to SF: So you prefer to work by yourself most times?*
>
> *SF: Yep*
>
> *R: And that's because...?*
>
> *SF: Oh, I like it, just independence, no one's disturbing me, no-one's getting in your way of learning, so, if I don't learn, well then that's my own fault.*

SD has moved out of the science learning area and into the adjoining open commons. He is sitting on his own, on the floor.

> *R to SD: Do you mind telling me a little bit about what you're doing, and why you've chosen to come out here…?*
>
> *SD: It's just…it's more quiet, and so I can actually do some work, and not get distracted by everyone.*

**2.17pm Curriculum: Learning choices in action: What to learn and why to learn it**

The heat practical students are standing at the practical benches, working in groups. In this internal *Investigate implications of heat for everyday life*, students can choose to investigate an issue of interest. I talk to one pair who are busy wrapping the sleeve of a bright pink puffer jacket carefully around a beaker of hot water. Puffer jackets are non-uniform items, but students much prefer them to the regulation school jackets. A school jacket also lies on the table, ready for testing.

> *R to SX: Can I ask you what you're up to?*
>
> *SX: We're testing how fast the water cools down, and then we're gonna do it with a school jacket, to see which material will keep the water warmer.*
>
> *R: What's your overall question in this practical?*
>
> *SX: To determine which material would be more suitable for a school jacket.*
>
> *R: Are you going to use it? The conclusions?*

*SX: I'm going to try to, because (a senior teacher) is like, the person who goes around and says '**Uniform!**' and I can go, like, well, **science** says…*

*R: Yes. You could put together a report and say...well actually…*

*SX: (finishing R's sentence) …we should be allowed to wear (puffer jackets) cos it's better for our health cos if we're warmer, we'll actually come to school instead of staying at home sick.*

**2.22pm Curriculum: Learning choices in action: What to learn and why to learn it**

I talk to another pair of students. Equipment is everywhere, and I was attracted by the chaos. I see beakers of water, Pink Batts, tinfoil, thermometers, and timers.

*R: Can you tell me what you're up to at the moment?*

*SW: Me and (ST) are doing what insulates a home the most. So what will keep heat in the longest.*

*R: Insulation in a house? How did you make that choice?*

*ST: Miss told us.*

*R: She gave you that idea?*

*ST: Yeah…*

*R: But you could have chosen something else?*

*ST: Yeah, but we just didn't know what to do, so we just let her figure it out for us….it was easy.*

*SW: Yeah, and cos my house is quite cold, sometimes.*

**2.31pm Space: Distractibility and motivation**

Although noise and distractions can sometimes be an issue, it seems as if the very visibility of the problem serves to help students to remain aware of the dangers and act against it. The responsibility is with the students, but they also have the power to do something about it.

*SG to R: Sometimes it can get quite noisy, so you just need to put music in, or just focus on what you're doing, not get distracted.*

That the learning 'matters' in a broader sense, is 'for' something (NCEA level one), provides motivation.

> *SD to R: It's very easy to do what you want and get distracted, and just talk.*
>
> *R: And so how is it possible that you actually can focus instead of talk?*
>
> *SD: Um, I don't know, I just want to pass! (laughs)*

**2.35pm Space: Learning choices in action: Where to learn: Ownership of space**

I talk to student A, who is working in TB's lab, but who tells me that he would prefer to be working in a quieter, less busy space.

> *SA to R: The only main thing I would say that can be quite distracting is the noise.*
>
> *R: So sometimes you'd like to shut out what else is going on so you can focus.*
>
> *SA: Yep.*

I notice a group of (possibly high social status) friends has claimed the breakout room and are interacting noisily in there, eating chocolates.

> *R: Is there anywhere you can go, to actually focus, say in one of those other rooms, or...*
>
> *SA (hesitant): ...Ah...you could...ahhhhh…if the people that are currently in those rooms didn't...you know... (monopolise them).*
>
> *R: Weren't in there.*
>
> *SA: Weren't in there. And they go in there and be very noisy so...*

So, I go and talk to the group who have claimed the breakout room. They seem to have ownership of this space. There are six of them, all seated around the same table, with books open and pens out. They offer me a chocolate.

> *R to group: Can you tell me a little bit about why you have chosen to be in here? Tell me what that's about.*

*SI: Um...just, it usually got really noisy out there and it was like, distracting...and like, in here...we still do our work, we still manage to do our work, and like…yeah, I just like sitting in here.*

*SK: Out there, it's sort of, way too crowded…*

TB enters the breakout room.

*R to TB: What are the rules for who gets to be in the breakout space?*

*TB: It's very much dependent on the teachers and the way they want to do it. Sometimes students ask to use the breakout space once, and they'll use it, they'll ask a second time, but then they get used to it… (and continue to use the space).*

**2.39pm Space: Noise and distractibility**

Walking through to the next-door commons, it is quite peaceful. A teacher is with a group of seven students who seem to be focussed on their workbooks. Another group of seniors is sitting around another table, working silently.

*TB to R: When people come in here, one of the comments I get is 'it's not as noisy as I thought it would be!'*

Moving back through to the science spaces, there is more energy and noise. TA is working with six different groups who are doing the heat practical. The sliders are shut to keep out the noise. I can see TB engaged with her little electricity group in the other lab. Groups of students are leaning over computers in the empty third space and working away. There is music playing quietly. A student wanders in to TA's lab from the nearby commons, just to visit, but he is shooed away.

**2.40pm Assessment: Keeping track as a 'guide on the side'**

I notice TB has finished with her group. The students stay seated and quiet, bent over a task she has assigned. She begins now to move around the students working independently on the physics of an application internal. As she visits each group, she sits down with them and takes out a little notebook to make a quick record of the learning conversation.

*TB to R: We have a little (shared) notebook and each student has their name at the top of a page and when we go and talk to them we write down the date and what we talked about. Just to keep track of what they're doing.*

*TB to R: I guess because the students know that it's more on them to get through the work that they're not as…. don't want to use the word but they're not as needy, so they're not constantly calling you over, so I do actually have the time to sit down with students.*

**2.48pm Assessment: Learning choices in action: Opting in to an external examination revision session**

As signalled earlier, the final 20 minutes of the session is for examination revision. The heat practical people working with TA begin to pack up, and TA opens the slider to issue an invitation to attend examination revision workshops. There are three external achievement standards that students could enter and therefore could be revising for. As well as mechanics for physics, the topic of acids and bases is tested for chemistry, and genetics for biology. However, in the flexible and modular credit system of NCEA, not all students enter all three.

*TA (speaking loudly to the whole group across all areas): Alright! If you would like to join a workshop on acids and bases, (TB) will meet you over here (gesturing to TB's area).*

*TA (continuing to speak to the whole group): If you would like to do some genetics revision, we are going to move into the breakout, where it's a bit quieter. We are going to do a quick revision of everything. If you have not looked at anything from term two, you should be coming to remember everything you need to remember. This isn't going to answer all your questions, it's going to be a refresher of the content, OK?*

At this point a student says vehemently and audibly, ***"No thanks!"***. This public rejection (which in a more traditional environment could possibly be construed as rude), elicits no observable reaction from either teacher. It was an invitation, after all.

Once the students who have opted to do so have moved to the workshop of their choice, I go and talk to the vocal dissenter.

> *R to SG: So ...you didn't want to join the (genetics) workshop...? Because…?*
>
> *SG: I'm interested in civil engineering, and I only need physics and chemistry for that, so by dropping biology and not studying for that, I can focus more on the other two.*

I talk to another student who continues to work individually.

> *R: So (TA) is offering workshops for anyone who wants to join, is that the story?*
>
> *SD: (continues working): Mnnn hmmm.*
>
> *R: Do you feel like she wants you to join?*
>
> *SD: No, no.*
>
> *R: She was just telling you in case you wanted to…*
>
> *SD: Yeah, she was telling everyone, to let them know.*

The workshops are intimate gatherings, and totally focussed. The teachers sit too, writing on a whiteboard table as ideas are developed and explained. Students are “carpentered” to the desk (McDermott, 1976, p. 43), crowding close, taking notes. There is no behaviour management, no ‘making’ the students listen. All are focussed, presumably because they have chosen to be there.

> *TB to her acids and bases workshop group: This is fluoride, this is chloride, this is... (students try to supply the answer) ...ammonium nitrate. Just like sulphate, it's got oxygen so attached to the end, it ends in 'ate'.*
>
> *TA to her genetics workshop group: Just remember, some people make silly, silly, mistakes with these Punnett squares. Remember how they work, right? **PRACTICE**! Always the big letter first, that's another mistake.*

Although the philosophy of student choice is key, some students are required by teachers to attend a workshop, or to work with teachers individually.

> *R to TB: What about the tail enders?*
>
> *TB: Sometimes, those who are struggling, they have no choice (about attending workshops). Sometimes we notice they didn't come for both (workshops), then on an individual basis we'll catch up with them. You cannot just leave it as it is.*

**3.10pm Digital: Learning choices in action: Homework pathways**

The teachers finish their workshops. TA again addresses the whole group. Various follow-up revision activities are offered for homework. Students are expected to think about what they need to do to progress and to choose the appropriate activity. TA explains that there are sets of revision questions at different levels in the three external topics on Google Classrooms. There are also links to flipped classroom videos which TB has made. For students who want more help, they can arrange to see a teacher and revisit the work. A milestone test for the physics external is available for those who feel ready for that. TA and students explain the philosophy that underpins the digital access and homework options as follows:

> *TA: They need to be able to manage themselves, or attempt to manage themselves. They need to be organised, they need to be reflective. I have high expectations that students will reflect after class. I've never set particular homework, because everyone's doing different stuff, you can't do that.*
>
> *SA to R: We can access all our work at home. If we don't finish it in class or if you are away for some reason you don't fall behind because you can access it at home.*
>
> *SB to R: All our work is on (Google Classrooms) and we can, like, talk to the teacher. Yeah...you email them and they can comment on parts of your work so you can change it.*
>
> *R: That's helpful. So you can really learn anywhere.*
>
> *SB: Anytime.*

**3.13pm I'm your teacher**

Near the end of the session, students are asked to pack up and move back to their own area with their own teacher, who is responsible for tracking their progress, marking their assessments, and reporting to parents. I listen to TA issue final instructions to her own group as she offers to support her students in their learning. She reminds them of where to go for help, what extra worksheets they could be doing, and where they should be up to.

> *R to TA: So you start with all your own students and you finish with them all together.*
>
> *TA: Yep, and I often have to remind them (students) that we're still accountable for our class. I still write my classes' reports, I mark my classes' exams, so I make it really clear to the kids that they have a teacher who's responsible for them.*
>
> *One of my students, I said to them, 'Oh, we need to have a conversation about your internals'. And she said, 'Oh, I talked to (TB)', and I said, 'Well that's great, but I'm your teacher, I need to know, I need to enter you, I need to mark you and I need to know what's going on'. And some of these kids they forget that. They can make decisions during class time, but they do belong, so if there's a parent question or whatever, we know who needs to manage it.*

**3.15pm Digital: Teacher accessibility**

Then I move into TB's area. TB invites her class to email or share their work, any time, for feedback.

> *TB: Quite a few of them will email both of us, separately. So actually they make use of that to get comments on their work.*
>
> *R: So they'll send the same piece of work to both teachers? That's quite a bit of extra work for teachers.*
>
> *TB Yes, that's true. But fair enough, you invite, if they pick up the invitation…*

Unlike TB, TA finds the emails and work-sharing over Google Docs intrusive, because for her, the constant accessibility at home means a 'teacher' identity sometimes outstays its welcome.

> *TA: (Another teacher) told me to take my school emails off my phone, because I was checking them at home and I was emailing them at home, and I was thinking I have to email this kid, and I have to do this, and she said you* **don't!** *They'll be there tomorrow, and you don't have to do it, that night. So that changed home life straight away.*

**3.20pm Space: Teacher accessibility**

Class has ended. Music plays, and students are released. All but three students disperse. They follow TA back to her glass-walled office, which adjoins the commons. They continue talking to her about their work.

> *R to TA: You're very accessible with your offices…*
>
> *TA: Very...overly…it's actually a current issue. You're literally surrounded by them and talking to them and having academic mentor conversations with them and pastoral meetings and guidance from 8am till 3:30pm.*

At this moment another student comes bowling up to tell TA where he will be working and what he will be doing the next day.

> *TA to R: Case in point!!*

**3.31pm Class has ended**

Everyone has dispersed at the end of the school day; the science spaces and commons are empty. I also, go home.

### *6.5.5 Interpretive discussion of portrait*

Fundamental to the enabling of personalised learning is the ability of the system to afford students choices in their learning. The portrait projects a picture of 21st century senior science learning where choices are available for students to different degrees along dimensions specified by *what, where, how, with whom, when,* and *why* they learn. The autonomy afforded to students across this spectrum of intersecting learning choices corresponds to meanings of deeply personalised learning proposed by Benade (2017a), Hursh (2007), and Leadbeater (2005, 2006) (see also section 4.1.1).

The portrait illustrates ways in which teachers might construct and experience the science learning environment and demonstrates how team teaching might enable them to offer different types of learning choices. Student voice data foregrounds the ways students might experience being science learners in flexible spaces and some of the ways in which they might be able or not able to use choices to personalise their learning. Their choices were enabled and constrained within possibilities afforded (or not) by the science curriculum and NCEA assessment when teamed with digital (and other) learning tools, and flexible learning spaces.

Choice in *what to learn* is depicted as supported by NZC as a framework curriculum, and simultaneously directed by NCEA assessment in the form of specific achievement standards. When two teachers worked together using the flexibility of the modular NCEA assessment system, it was possible to offer students the option of gaining science credits by undertaking a range of internal or external achievement standards. Student choice in *where to learn* at school was supported by the flexibility and agility of space. Students were at liberty to move to a preferred work-space within the science areas and even out in the adjacent commons, sitting alone or with others. There were many choices available in *how to learn* which were afforded by digital technologies, printed workbook support, group work, or opting in to a workshop session. *When to learn* was supported by online digital environments enabling out-of-hours access to the teachers, as well as by using workbooks to support conventional home learning. Choices in *who to learn* with were enabled by team teaching across flexible spaces. Students might be able to choose *what to learn* and at times, *with whom*, however, relationship and group cohesion are important. The portrait illustrates ways teachers might work together with a large group of students in a flexible science space to enable learning choices to be offered, while at the same time maintaining a relationship with a class of their own.

While digital technologies were not the only choice students had in supporting independent learning, the portrait demonstrated digital technologies acting as enablers which allowed students to make choices about *how to learn, when,* and *where*. Using digital technologies, students were able to access information and to connect with teachers anywhere, anytime, including outside of school hours. For one teacher, this convenience for students caused issues associated with 'over-accessibility'. Unless they set limits, teachers in the portrait were constantly available via digital communication both at school and at home.

In considering *what* and *why to learn*, the portrait reflected students' different science learning motivations and orientations. While concerns with ease of achievement and gaining credits were motivation for some, others were oriented to more interest-based learning. Some students wanted to apply the laws of physics to their favourite sporting context. Others chose to get a head start on the complexities of level two physics as a specialist science discipline. For others again, the internal heat transfer standard was relevant to personal contexts.

A theme highlighted by literature on 21$^{st}$ century competencies and personalised learning (e.g. Deed et al., 2014; Griffin et al., 2012; Ministry of Education, 2015c; Voogt & Roblin, 2012), and integral to the discourse of 21$^{st}$ century learning is the level of independence and self-management required from students. Students are positioned as in charge and able to make their own learning decisions, but as also needing solid support when necessary (Katz & Assor, 2007; Yonezawa & Jones, 2007). Teachers' roles in the portrait included those of 'expert-enablers'. This meant orchestrating learning by assisting students to take on and to sustain these self-managed identities. It was necessary for teachers to keep track of student progress and sometimes students had no choice. For the *"tail enders"*, teachers acted as 'taskmasters' to safeguard their progress and achievement.

Related to this theme are issues of noise and distractibility associated with open spaces. During the session, researcher observations were used to notice these. Students and teachers were mostly proactive in exploiting the agility of spaces to mitigate any issues. Teachers closed the glass sliders and students moved themselves away from distractions. As seen in the episode involving the use (or misuse) of the breakout room, managing space sometimes necessitates prior planning and intentional rule-setting if students who need it are to be provided with a peaceful escape. Breakout space can be used for interactive group work or by allocating it as a quiet work area. In the portrait, the group of students in the break out room were perhaps more relaxed and less productive than they could have been. This highlights difficulties for teachers in supervising and supporting many individuals on different tracks in different spaces, especially if they are spending focussed time with one small group.

For students who choose to enter them, the external achievement standards construct science within the discourse of traditional, knowledge-based learning. This positions the teacher as expert in transmission mode, and positions students as needing to understand and remember science concepts. Stanton Wortham (2001) presents an insightful constructionist critique of the teacher-as-expert transmission position. He argues that the knowledge presented in a lecture or lesson takes significant time to prepare. A teacher spends time reading and making notes, preparing resources and structuring material, but conducts this process off-stage and behind the scenes. Wortham argues that this off-stage construction denies students access to learning about processes of knowledge construction, which they need if they are to engage and interact with knowledge as more than just recipients. The relevance for science is that traditional teacher-transmission might also serve to further reinforce the teacher-as-expert/student-recipient divide, where science is seen as knowledge-based, difficult or inaccessible, reserved only for those special few who are capable of engaging in more traditional science student acts of listening, taking notes, and memorising facts (Carlone, 2012; Tytler, 2007).

However, 21st century environments are specifically designed to enhance the provision of more student-centred pedagogies, and this discourse eschews one-size-fits-all, delivery approaches. In the portrait, the teacher-as-expert rarely appeared to the whole group of two classes. Instead, by offering workshops where students opted in to learn new concepts or to revise, the teacher-as-expert appeared only to those who chose to engage. Students in workshop sessions were described as being carpentered to the table, leaning in and concentrating on the goings-on. The term is used by McDermott in his stunning study of orderliness and interruption in first grade reading circles, to create a picture of student engagement by their physical positioning and body language of leaning in, forearms flat on the table, taking a position of being a focussed and engaged student (McDermott, 1976). Offering choices to students is related to increased focus, engagement, and motivation in student-choice literature (Katz & Assor, 2007). The brief but focussed workshops managed to unite 21st century personalised ideals with effective, but traditional, teacher-as-expert approaches. At other times, teachers were expert-enablers who might suggest options and facilitate progress by visiting individual students as they worked independently on various tracks.

In this section, the technique of portraiture has been used to weave together data from all three case studies to illustrate themes and categories arising from the interplay of elements of curriculum, assessment, flexible spaces and digital technologies. A combination of participant quotes and close descriptions in the form of researcher observations was used to notice the good, such as focussed, engaged students in workshop sessions, and to highlight possible challenges, such as issues associated with student access to breakout spaces (Lawrence-Lightfoot, 2005; Yin, 2014). Overall, this portrait has demonstrated what science learning might look like in personalised environments.

A discourse of 21$^{st}$ century learning supports student identities of independent (yet in community), self-directed learners, with diverse needs. The next step in phase two is a close investigation of what happens when students are offered positions as self-directed learners. In asking "what *could* learning look like", phase two action research attempts to take steps towards enacting a 21$^{st}$ century discourse view which shapes learning as diverse and meaningful, with individual students on personalised pathways. What can this look like within the practical reality of senior science schooling? How do students take up identities as self-directed learners and make choices, and under what motivations and rationales? What is the teacher's role? What influence do the four elements have? Chapters seven and eight present qualitative and quantitative data as outcomes from three cycles of action research which enquires into these issues.

# Chapter seven: Phase two action research cycles one and two

Phase one used case study and portraiture to present an overall picture of science learning and to demonstrate the possibilities for different identities that teachers and students were enacting. Phase two is a longer-term and more in-depth examination of happenings in a science class at case study school two, over three cycles of collaborative action research. The focus for this phase was on what science learning *could* look like when students were intentionally positioned as choice-makers, and learning constructed as personalised and student-directed. Different types of inquiry learning were used as vehicles for facilitating personalised pathways in senior science.

Chapter seven presents data and findings from the first two cycles of action research and is divided into four sections. First in section 7.1, the initial stages of collaboration between myself and the teacher are detailed. The class context is described, and eight focus students are introduced. To set the scene, I briefly describe class activities before the beginning of action cycle one. Although not an action research cycle as such, this section is concluded with an evaluation and interpretive discussion. Section 7.2 presents data and findings from action cycle one and section 7.3 presents findings from cycle two. These sections are concluded by an evaluation and interpretive discussion where the outcomes of each cycle are presented in the form of quantitative student achievement data, followed by a discussion in which aspects of discourse analysis are presented.

## 7.1 Getting started with action research

Level two (year 12) general science was offered to students at school two for the first time in 2017. This was an extra offering on top of discipline-based courses of physics, chemistry, and biology. General science as a 14 credit, level three course made up of any combination of credits from biology, chemistry, physics, earth science, pūtaiao[3], or education for sustainability is an approved subject for university entrance (NZQA, n.d.-a).

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[3] Pūtaiao is the science learning area in Te Marautanga o Aotearoa. The Marautanga sets the direction for teaching and learning, and describes skills, values and attitudes appropriate to Māori medium kura (schools). The National Curriculum consists of The New Zealand Curriculum (NZC) and Te Marautanga o Aotearoa. Te Marautanga reflects a te ao Māori view (Māori worldview) and is not a translation of the NZC.

This means that a general science course is a viable option for students who are focussed on entering vocational careers immediately upon leaving school as well as for those who might go on to university.

I was interested in joining with this class and their teacher for the action research because:

1. This was a new course so was less likely to be influenced by previous practices or ways of teaching and learning.
2. A general science course at level two could mean more flexibility in terms of potential science disciplinary areas and opportunities for science inquiries within different achievement standards.
3. I wanted whole class participation, or as many students to volunteer to participate as possible. Year 12 students are mostly 16 years old and therefore able to give their own consent. In phase one, the process of sending notices home to students who were 15 years and under (the easy part) to be signed by parents and returned (the difficult and time-consuming part) meant that not all students in the classes participated in the study.

One aspect that concerned me was that as science concepts become more specialised and complex at level two as compared with level one, each teacher becomes responsible for their own class within their own specialist discipline and specialist achievement standards. I could see that this might leave less opportunity for personalising learning via team teaching approaches as illustrated in the portrait at level one science. However, in theory, collaboration between classes and team teaching was still possible, as three level two classes were timetabled at once. The general science class was positioned in the middle of three science areas; when the general science class was on, visible through the glass sliders next door were level two physics in one area and level two biology in the other.

### *7.1.1 Planning for action research*

**Curriculum decisions**

The teacher and I met early in the school year to discuss the research. We contrasted the flexibility that was possible in junior secondary science (years nine and ten) with senior science (especially years 12 and 13), where according to the teacher, a personalised or inquiry-based curriculum is abandoned due to the focus on gaining NCEA credits. We discussed expectations inherent within the NZC that learning is to be relevant and meaningful to each student (Ministry of Education, 2015b). We also discussed the challenges issued in a Ministry of Education discussion document, which looks towards New Zealand education in 2025. Key attributes of 21$^{st}$ century learning are listed in this document as: self-directed learning, empathetic, inclusive, innovative, and collaborative learning, authentic problem solving, and STEM foundation for all (Ministry of Education, 2015c, p. 2). Possible characteristics of a connected education system in 2025 are also listed. These include that diversity flourishes, the learner chooses their own path, technology is harnessed to provide collaborative links with agencies and groups/whanau outside school, and learning to learn and lifelong learning is key for all ages, anywhere, anytime. In this system, teachers are learning advisors who help with goal setting, advise on learning pathways, and provide a mix of direct and guided instruction (Ministry of Education, 2015c, p. 1).

The teacher and I discussed the following questions: What does 21$^{st}$ century senior science learning look like in practice? At what point do 21$^{st}$ century learning ideals begin to engage with the reality of gaining qualifications in senior school? What does self-directed learning, where the learner chooses their own path, look like for students of senior science (Ministry of Education, 2015c)?

Bolstad and Gilbert observed in 2012 that “personalised learning is not well understood and implemented only in a limited way in a small number of schools” and that there is “no model out there, waiting to be found” (p. 48) (see also section 1.5). Five years later, in 2017 as we began action research, the teacher in her new and state-of-the-art flexible learning space school echoed these thoughts:

> *Teacher: In terms of personalised learning and what we want to do - it looks like we won't find anyone to tell us how to do that. It looks like we're just going to have to do it.*

By undertaking action research, we decided we could contribute something to part of the eventual picture of what personalised senior science learning might look like. Our aim was to explore models and possibilities for more personalised learning in NCEA level two science.

There were various course designs to consider. One option would be for the teacher to design a theme-based course (the human body, forensic science, transport, science of sport). Another option would be an issues-based course such as the study of socio-scientific issues (waterway pollution, 1080 poisoning, climate change) (Hipkins et al., 2016, p. 158). Courses such as these would arguably offer curriculum coherence but ultimately would be less effective in offering students the ability to make their own curriculum decisions. We felt these options would place the teacher in the driver's seat and expect students to buy into the teacher's own interests and learning goals. We did not want to assume that what interests the teacher will be interesting, relevant, or meaningful to the whole class (Olitsky, 2005; Seiler, 2013). Instead, students were asked, *"What floats your boat?* We acknowledged that the answer might be different for every individual. The teacher surveyed the students at the start of the year, and it was decided that the course would loosely follow the earth science curriculum strand because many students expressed interest in this area. This was with the understanding that if students later chose to diverge from this path and learn within another science curriculum strand, they would be permitted to do so.

**Overall plan for three cycles of action research**

Three successive cycles of action research sought to progressively open up options for students in terms of contexts for science learning, pathways through science learning, and students' own science questions. In the first cycle, students could choose any relevant context within a single NCEA earth science achievement standard. In cycle two, students again could choose any context, and as well they developed inquiry questions leading towards achieving the criteria within a set standard. In cycle three, rather than assessment criteria dictating what was learnt, students were given the option of generating their own inquiry or problem-based questions, which we then attempted to 'fit' into the level two science standards. Guided by an ethos of choice, flexibility, and student-owned decisions, we attempted as far as possible to accommodate students' learning needs. For example, for students to be eligible for subject endorsement they must gain credits in at least one external standard. Learning for science externals would be resourced and supported for those who wanted to attempt this. We also supported those students who wanted to learn within other disciplines, such as biology. In this sense we were offering students opportunities to choose their learning pathways while simultaneously assuming, and testing, the flexibilities and affordances for learning offered within science curriculum, NCEA assessment, flexible learning spaces, and digital technologies.

**Teacher and researcher roles**

We discussed our roles and responsibilities within the research. The teacher was the learning leader with responsibility for curriculum and assessment decisions, students' progress and learning. As researcher I would be the commentator, critical questioner, 'writer-upper' and resource person. I would interview students and collect relevant data. Together we would reflect and collaborate. We agreed to ongoing conversations and check-ins as the research progressed, which I recorded and transcribed for later reflection. As it turned out, our informal, ongoing conversations and reflections were a constant and characteristic aspect of the action research.

### *7.1.2 The learning space*

The science learning happened in a laboratory space which opened onto two other laboratory spaces. The three spaces were arranged in an 'L' shape. Benches for practical work ran along two walls and along part of a third wall, which also opened onto the biology space. The fourth wall was half whiteboard, half glass cavity slider, opening into the physics area. The layout of the room and glass walls meant that standing in the science class, you could see through to a level two physics class and a level two biology class which were scheduled at the same time.

### *7.1.3 The science class*

The class was populated with 27 (according to the teacher) *"interesting characters".* Central to the teacher's original decision to offer a level two general science course was her awareness of a large group of students who were interested in continuing with senior science but who for various reasons would not have opted into or been accepted into a discipline-based course such as chemistry or physics.

> *Teacher: What I've realised over the years is that we weren't catering for those who didn't want to specialise (in a science discipline) but that wanted to keep their options open, which means that we were losing those students to science. I surveyed*

> *kids who said, 'I really like science, I just didn't want to do… (biology, chemistry, or physics).'*

Many students who opted for this course were not interested at that time in pursuing a science-related career, yet were still interested in science, and saw it as relevant or important for their futures. Many students would not have been considered as candidates for the discipline-based courses (biology, chemistry, physics) due to their patchy successes in level one NCEA. The teacher counted 19 students from a starting group of 27 who would not have been accepted into a discipline-based course based on their level one NCEA external results. These 19 students had no level one external science credits. Prerequisites for entry to the level two science disciplines were an Achieved grade or better in the relevant standard. For example, an Achieved grade in the level one physics external would allow the student into level two physics, but not level two biology or chemistry.

> *Teacher: Students in this class would not necessarily have the prerequisites to get into the discipline-based science courses such as physics, yet they wanted to continue with science study.*

Students themselves perceived the general course as more accessible than the discipline-based level two courses. At least two students moved from biology and physics into general science during the first few weeks of the school year. Student L moved from biology. He told me that he would rather be in the general science class than *"in (biology) struggling and not getting credits".* He exclaimed: *"I'm not learning in there, I'm just copying things down,* **no clue.** *I don't even know what a mitochondria* ***is****!"*

The focus for the level two general science class was to be on developing science capabilities, scientific literacy, and on supporting students to engage in aspects of science study which would be of interest and helpful to them as individuals. The teacher predicted that some students would *"struggle with literacy"* and would need time to familiarise themselves with science-specific vocabulary and knowledges and to develop these to a level two standard.

She was also cognisant of the fact that many students complete far in excess of the number of credits required to achieve level two (Hipkins et al., 2016). She therefore decided the focus for the course would be on quality of learning rather than quantity.

> *Teacher: Students can think about what they need, think about what their goals are, what's achievable, focus on quality rather than quantity.*

While students in other courses commonly complete as many as 23 or 24 credits, (Hipkins et al., 2016), the teacher took a decision early on not to be beguiled into attempting excess credits at the expense of leaving students behind. A total of 60 credits is required to achieve NCEA level two. Students were able to choose five courses in total, including science. It was decided they needed to be given opportunity to attempt a minimum of 14 credits in the science course, although students could complete more if desired.

Many of the students in the class were on a vocational path and were involved in courses such as Future Directions and Trades Academy. These courses provided opportunities for work experience and trades-related learning at Polytechnic. There was much coming and going, with almost half of the class out on Fridays at Trades Academy. Students also missed class because of other career-related training, such as a three-day First Aid course. Longer blocks (90 minutes as opposed to 50 or 60-minute classes) meant students missed more class time if they missed a day. It was for these reasons also that the teacher was not overly ambitious with the number of credits attempted.

Wallace and Priestley (2017) position teachers as curriculum creators, “intelligent decision makers who interpret and modify the official curriculum in accordance with what they believe are the needs of their students and also to align with their own moral and educational beliefs” (p. 324). In the responsive decisions she was making on behalf of her year 12 students, the teacher was doing just that.

**Introducing focus students**

As I began the action research, getting to know all students was a priority. I set out over a two-week period to individually interview every student who had volunteered to participate. I was interested in their reasons for choosing the science course and how they saw science fitting with or aiding their future plans for work or study. I reasoned that students who are positioned as self-directed learners need to have at least some idea of their strengths, needs, and interests, and some thoughts about what they might need from school for their future careers.

While I followed all individuals in the class, I selected a group of eight students to focus on and to follow more closely. These eight students who feature across the three cycles of action research are introduced in Table 1 below.

***Table 1: Focus student details***

| *Student details* | *Student information* |
|---|---|
| Anahera<br>16 years<br>Female | Anahera had *"no idea what I want to be when I'm older"* but thought science was an important subject to learn.<br>She was interested in disciplines of earth science and physics and wanted an endorsement in science. |
| | *Level two courses:* English, mathematics, dance, geography, science |
| | *Level one science credits:* 14 internal, four external |
| Anshu<br>16 years<br>Female | Anshu wanted to study Law at university and chose science only because she *"had a gap"* in her timetable.<br>She was interested in biology as a discipline because *"I find it a bit easier than the other ones."* |
| | *Level two courses:* English, mathematics, health, history, science |
| | *Level one science credits:* 15 internal, no external |
| Haeata<br>15 years<br>Male | Haeata wanted to be a pilot or a veterinarian.<br>*Researcher: Do you know what subjects you need for those careers?*<br>*Haeata: Vet, I need biology and English and for pilot I need English and physics.*<br>*Researcher: You've chosen science rather than biology and physics?*<br>*Haeata: I couldn't decide, and this is a mix.* |
| | *Level two courses:* English, mathematics, media studies, music, science |
| | *Level one science credits:* 17 internal, eight external |
| Jeff<br>16 years<br>Male | Jeff was leaving school to begin a building apprenticeship at the end of the year. Jeff originally chose physics but swapped into science during term one.<br>*Jeff: Last year I thought I was going to be an engineer then when I got to becoming a builder I didn't really need physics.* |

| | |
|---|---|
| | *Level two courses:* English, mathematics, Future Directions, hard materials, science |
| | *Level one science credits:* 17 internal, eight external |
| Joseph<br>16 years<br>Male | Joseph had many ideas about what he could do when he left school. One idea was to complete a mechanics apprenticeship, and then *"work on cars or on superyachts"*.<br>*Researcher: Why science?*<br>*Joseph: I was going to choose physics but then (general science) came up and it seemed like a lot better option because if I don't go straight to mechanics I will have some biology and chemistry to fall back on. So, for example, if I feel like being a Chiropractor I will have biology.* |
| | *Level two courses:* English, mathematics, sports science, Future Directions, science |
| | *Level one science credits:* 11 internal, no external |
| Sophie<br>16 years<br>Female | Cello-playing Sophie was interested in Vet Nursing or studying microbiology at university. Earth science also interested her.<br>Sophie chose science because it *"had a bit of all the sciences"* and because she could make earth science links to this component in geography: *"I get to learn about earth science, space, volcanoes in a scientific way."* |
| | *Level two courses:* English, mathematics, geography, music, science |
| | *Level one science credits:* 12 internal, four external |
| Taabah<br>16 years<br>Female | Taabah joined the class from another secondary school late in May 2017 (week 4, term 2). Taabah was interested in biology, but especially genetics.<br>*Researcher: Why join this class – you could have joined biology?*<br>*Taabah: I don't know…easy credits.* |
| | *Level two courses:* English, mathematics, classical studies, digital technology, science |
| | *Level one science credits:* 12 internal, four external |
| Tangaroa<br>16 years<br>Male | Tangaroa was interested in pursuing a career in engineering or sports teaching.<br>He chose science because he could *"do all the other subjects and science rather than just biology or just chemistry".* Tangaroa was interested in disciplines of physics (for engineering), earth science, and astronomy. |
| | *Level two courses:* English, Te Reo Māori, physical education, outdoor education, science |
| | *Level one science credits:* 10 internal, no external |

### *7.1.4 Class activities before beginning action cycle one*

At the beginning of the year the teacher needed to establish her modus operandi and build relationship with students. Students in this course had varied (and in some cases limited) prior success in science, and for the first few weeks of the year (March 2017) before beginning action research, the teacher had wisely decided upon a structured start with a hands-on, skills-based Microscope standard:

> AS91160 **Biology 2.8:** Investigate biological material at the microscopic level
>
> 3 credits Internal
>
> (NZQA, n.d.-e).

Although related to the discipline of biology and the Living World curriculum strand rather than the earth science or Planet Earth and Beyond strand, the teacher reasoned that the structured, practical learning within this standard would set the tone with achievement and interest.

> *Teacher: To build some relationships and give them a bit of success. They can learn about me and how I operate, and I can learn about them and their quirks.*

In this task students were assessed on the practical skills of preparing specimens and microscope slides and using the microscope to view the slide. Students were also assessed on their ability to complete biological drawings and annotations using accepted conventions. The highest grade that could be awarded in this standard was Merit. Learning involved skills of scientific drawing, practical skills of slide preparation and microscope use, observation, and knowledge of cell structure and function. The teacher prepared a workbook which structured information and exercises to guide students through necessary achievement criteria. At this early stage of the year the teacher distributed the workbooks and collected them at the end of each session, which she described as *"a bit Mumsy"* for year 12 students, however, she reasoned that some students in the class needed this level of support.

This learning activity, which was not a focus for the action research, was successful in achieving its goals. The students enjoyed the practical component and were very focussed on completing their diagrams and workbook tasks. Most students in the class gained credits for their work (11 Merit, 14 Achieved, two Not Achieved). The teacher remarked at the conclusion of this standard that *"I think I've got them all feeling confident".* At the same time, in terms of students going on to achieve in the science course, she anticipated that *"I feel like they're gonna get there".*

### *7.1.5 Interpretive discussion*

This discussion analyses the influence of future career goals, interest in and perceived relevance of science, and the need to gain credits in NCEA on students' identities as decision makers. It also discusses the teacher's rationale for curriculum decision-making.

While the discipline-based courses of chemistry, biology, and physics allow for traditional academic science learning with prerequisites restricting entry, flexibilities within the design of both curriculum and assessment were exploited to offer this more general (although earth science focussed) course, open to all science learners. Many students, (e.g. Sophie, Joseph, Tangaroa, Anahera, and Haeata) saw science learning as relevant to their careers. Jeff had opted out of physics which he found challenging, and into science, once he knew he was going to be a builder rather than an engineer, and *"didn't need physics".* Other students had chosen the course because they considered science was important to learn for their futures more generally. When I asked student S why he chose science he emphasised this aspect. He told me that did not *"really need"* science for his future automotive apprenticeship, however, he reasoned that *"Science is everywhere – learning about it helps you learn more about the world you live in, what you do".* Joseph and Haeata saw science as a way of keeping their options for future study or employment open. While Tangaroa expressed interest in studying engineering or sports science at tertiary level, his subject choices (he was not taking mathematics or physics) were more likely to allow him to study sports science than engineering at university. Taabah saw science as an easy option to gain credits towards her level two qualification. Student S echoed the thoughts of many others (e.g. Anahera, Haeata, Sophie, Tangaroa, Student T, Student J4, Student M, Student F, Student C) as he explained that the course: *"Had all the sciences in it, I didn't want a separate science. It has lots of internals and I can gain heaps of credits from it."* For student N and student B, science was their second choice. They wanted to do biology but had not achieved in the requisite level one biology external. Sophie trusted in the flexibility of the course to meet her needs, while Anshu chose science to fill *"a gap"* in her timetable. These motivations fit with Katz and Assor's (2007) description of choice as needing to fulfil needs for autonomy and relatedness (see also section 4.1.2).

A critical point for students in the study was their decision to continue to learn science as a senior student. By choosing this general science course, students were accorded the right to take up 'science learner' identities and had opportunity to achieve science credits and qualifications without being channelled down a single disciplinary path. This could be considered a step towards enabling the diverse science learner identities envisioned in the senior curriculum guide, which points out the need to redesign flexible science programmes to include "diverse learning pathways" (Ministry of Education, 2015b, para. 3, and see section 3.3.2).

The need to ensure students' success in NCEA was key, and the element of assessment seemed to exert a strong influence on teacher curriculum decision-making. The course was decided by the teacher in terms of a flexible curriculum response to student interests (the earth science focus) while cognisant of the number of credits students would need (14 credits over the year). The Microscope standard was chosen for reasons of student enjoyment, opportunities for practical work, relationship development, and achievability. In making these decisions the teacher was taking steps towards the opening up of learning to more student choice. In the early stages of the year she was simultaneously executing her duty to help students achieve credits and seeking to position students by their early success as 'able to achieve'. In line with Shier's (2006) observation, it was not possible to state at the outset: "OK kids, it's your education, it's up to you now to run it yourselves" (p. 16).

In sum, flexibility in curriculum and assessment systems was exploited to offer a general science course to a diverse group of learners who wanted to continue with science at senior level. The gaining of credits featured in decision-making processes for teacher and students.

The next section presents outcomes of action cycle one.

## 7.2 Cycle one: What to learn within structured inquiry

This section presents data and findings from the first cycle of action research and was conducted during the second half of term one (March – April 2017). First the action research intervention is explained. I then move to report on student choices and how they made those choices, before reporting on learning progressions and students' progress to task completion. In the subsequent interpretive discussion, I analyse what learning looked like in terms of student and teacher identities.

### *7.2.1 Explaining the intervention*

In exploring what learning *could* look like, cycle one explored a fundamental approach to personalising learning. Firstly, the aim was to investigate how and why students were able to choose their own contexts within a single earth science achievement standard and what types of support they might need. Secondly, the aim was to document learning progressions and analyse the impact of the four elements on student learning.

The teacher began by allowing students to choose any context within the level two achievement standard which was decided upon by the teacher:

> AS91190 **Earth and Space Science 2.4**: Investigate how organisms survive in an extreme environment
> 4 credits Internal
>
> (NZQA, n.d.-e).

The standard chosen was an internally assessed research investigation which linked to the New Zealand curriculum within the level seven Living World achievement objective: Life processes (Ministry of Education, 2015b). Students could opt to pursue their study in two ways. They could choose an organism and investigate adaptations that allow it to survive in its environment, or they could examine technological innovations that allow humans to survive in space.

The task at Achieved level required students to select and process information to describe why the conditions of an extreme environment require special biological adaptations or technological modifications for survival. Students then had to describe how the biological adaptations or technological modifications allow the organism(s) to survive in the extreme environment. Merit and Excellence level required that students make links between the environmental conditions and the adaptations/modifications and to explain in depth how the adaptations/modifications allow the organism to survive (NZQA, n.d.-e).

*Week 6, term 1*

In the early stages of learning the teacher took the lead in knowledge-building and skills development. Progress towards the final assessment started with knowledge-scaffolding sessions where the teacher introduced key concepts and language to do with adaptations, survival and extreme environments. To do this she used readings, discussions, and videos as resources. A definition for 'extreme environment' was discussed and explained:

> *Teacher to whole class: Somewhere where it wouldn't be possible to just go there and live without special adaptations or technology.*

Both options were covered in these initial sessions; organisms in extreme environments and humans/technology in extreme environments. This meant students were exposed to wider learning in the form of important concepts and vocabulary associated with each option and were also more likely to be able to make informed choices about which path they would take.

To stimulate thinking about the technologies needed to survive in space, students watched clips of the science fiction film, *The Martian*, and completed an exercise titled 'MRS GREN in space'. MRS GREN is a well-known acronym representing the necessary features of life (movement, respiration, sensitivity, growth, reproduction, excretion, nutrition). The task was designed to stimulate students' thinking about the types of technologies necessary to support various aspects of life in space.

*Week 7 and beginning of week 8, term 1*

Students next watched a nature documentary, *The March of the Penguins,* and were expected to take notes on characteristics of the extreme environment and penguin adaptations. To support them in this, the teacher periodically stopped the video to highlight information.

> *Teacher: So, if you think about the penguin, there could be structural adaptations such as feathers and the layer of blubber,*

*the way their feet are used to move the egg, or behavioural – how they huddle, how they call.*

The teacher wanted to scaffold students into their *"actual"* assessment with a practise assessment task. For this she used the context of penguins in Antarctica.

*This task will be checked by your teacher and advice given for your actual assessment (Text on the penguin practise task sheet).*

Students used resources provided by the teacher to complete the task, and all students worked within this one context. The teacher printed off exemplars for each grade boundary from the NZQA website (NZQA, n.d.-e). She used these documents as she worked her way around the class to give formative feedback to individual students about this practise task before they were permitted to get started on the summative task. Following this preparation, the teacher felt confident that with support, most students would at least be able to gain an Achieved grade.

*Teacher: I figure that most of the Achieveds are doable with a bit of herding, it's the higher level that's gonna be the problem.*

The teacher next moved the students on to the *"actual"* assessment task, where they were to be given choices, and began to show students some options.

### *7.2.2 Making choices*

*Week 8, term 1*

This section presents data from teacher and students about the context choices they made. The teacher wondered if choosing contexts would be an issue for some students and noted that she may need to scaffold a few options for them. Students were provided with lists of ideas for extreme environments and organisms. As students decided on their topics, the teacher moved from group to group, repeating the same message about choices and noting down students' contexts as they made their decisions.

Teacher to one table of five students:

*I have a whole heap of suggestions. So, you can do another organism that lives in the Antarctic or Artic, organisms that live in the deep ocean, isolated environments…A unique ecosystem counts as being an extreme environment, so, for example, Galapagos tortoise. There are a whole lot of other interesting ones that I don't really know much about, so, extremophiles that live in really high temperatures and pressures, volcanic worms, Pompeii worm, ones that withstand radiation. If there is anything else, I am open to suggestions.*

Some students accessed ideas on the list; others chose from their own ideas and interests. I reintroduce some of the focus students and the choices they made below. These conversations happened in week eight after the preliminary teaching and scaffolding sessions.

**Sophie**

Sophie decided to do the humans in space option. She had enjoyed *The Martian* and borrowed the DVD from the teacher to take home and watch again.

*Sophie: I want to know if you can actually grow potatoes out of your own poo (as happened in the movie).*

**Haeata**

Haeata chose the Alaskan Wood Frog from a list of options the teacher provided.

*Researcher: Does it make a difference, being able to choose?*

*Haeata: Yes, because if the teacher said, 'we're all doing penguins', I'd be like, 'oh, more work!' But if it's something I'm interested in, like a frog that basically freezes, then I'll be more wanting to do it.*

**Anahera**

Anahera decided on Antarctic fur seals so that she could build on her knowledge of Antarctica as an extreme environment.

*Researcher: What helped you decide on that?*

*Anahera: They are in Antarctica and I've already watched the movie.*

**Anshu**

Anshu was unsure at first.

> *Researcher: Is there anything that interests you in the way of contexts?*
>
> *Anshu: Not sure. I'll probably choose the easiest to do or I'll do the most common one.*

She later decided on sharks, which was not the most common choice at all, as she was the only student in the class to do so.

**Joseph**

Joseph was interested in wolves. At first his research on YouTube and the internet led him to wanting to study the Dire Wolf – which is an extinct species, however, he later settled on the Arctic Wolf.

> *Joseph: I asked teacher if I could do it – first I researched what the extreme environment was, and she said yes.*

**Jeff**

At first, Jeff was interested in studying humans in space. Then, as he talked with the teacher about what he needed to do for the standard, he decided that the organism in extreme environment route might be easier to research.

> *Researcher: Are you thinking of any organism or environment that piques your interest? How are you going to make that choice?*
>
> *Jeff: I'm going to look around on the internet for something. I kind of like the humans in space (option) but I think the organisms one will be easier for me to do.*

When I talked again with Jeff again two sessions later he settled back on astronauts in space, even though he perceived this option as the more difficult one.

> *Researcher: So you were thinking about doing organisms because it was easier, but then you decided to let interest overtake that?*
>
> *Jeff: Yes, I'd rather learn something about it.*

Other contexts and reasons for choices included:

- Humans on Everest: Student B saw the movie *Everest* which sparked interest but also supplied useful prior knowledge.
- Snow leopard: *Because it's a leopard and it's disappeared…* (Endangered but not yet extinct) (Student J1).
- Tardigrade/Water bear: *Before I even started this (achievement standard) I saw a video about it and they can survive anywhere apparently, like…anywhere, like…volcanoes and space* (Student N).
- Squid in the deep ocean: Student C was interested in ideas of water pressure in the deep ocean: *Cos stuff gets squished...but (squid) don't, like… freaky!*
- Bactrian camel: *I wanted to do the penguins (but was not permitted as that context was used for the practise assessment), so I was like…OK, I'll go the opposite, I'll go with the desert, and I chose the camel* (Student M3).
- Humans in space: *From the movie, it was really cool and I wanted to learn more about it* (Student S).

### *7.2.3 Student progress to task completion*

*Weeks 8-11, term 1*

This section describes teacher and student actions, and how they were or were not able to make use of elements of space and technology as they worked to complete their internal assessment. I present one case in more detail to show how Joseph was able to take a different and personalised approach to assessment.

As this was a research standard and students were working with self-selected contexts, students worked independently, with individual teacher support and feedback. They exploited the flexibility of the learning environment to choose their work space. A pattern seemed to be established where the teacher would give the class initial brief instructions, then allow them to disperse. She would give them time to get settled before beginning to circulate, checking up on progress and offering help where needed.

*Week 8, term 1*

> *Researcher observation into voice recorder: Some students went off to work upstairs. When I went upstairs to visit, the music was on, but they were working.*

I talked to Joseph who was sitting on the floor in the biology area with another student. With their laptops open, they were working. The biology teacher was standing at her whiteboard and speaking to her class. Next door it was busier, with groups of students working and talking together.

> *Researcher to Joseph: You're sitting out here….am I allowed to know why?*
>
> *Joseph: Because I prefer to be out here instead of in the class all the time, because I find it easier to concentrate here.*

Students accessed technology to find, store, and present information. They used a range of devices; some used their phones, some borrowed a school laptop, and others used a personal laptop. Sometimes, a lack of access to technology caused issues. The school did not have a BYOD policy (bring your own device) and many students opted not to bring a device, stating reasons such as the devices were heavy or they were afraid of damage or loss. At times when there were not enough school laptops available, I would sometimes come across a student sitting doing nothing because they did not have a device. In cases like this, students were sent by the teacher to borrow devices from other departments.

The teacher used Google Docs during sessions to track progress for those students who were not immediately within her sight. For example, student M1 had been working in another part of the commons, but the teacher had commented in his document a couple of times over the session. He arrived back at the end of the session:

> *Student M1 to teacher: Miss, you're checking up on me!*

*Week 9, term 1*

Students were given a deadline of the end of week 11 to finish their standard and hand it in.

*Researcher observation into voice recorder: Today the class seemed very focussed. There is a deadline for this standard at the end of term.*

The teacher also began to put more pressure on students. She gave time signals and specified what sections of work she wanted finished, by when. As it was an internal assessment at level two, she was careful about the type of help she gave to students.

*Teacher to Sophie: It's level two, so with year 11, I can give you direction, and at year 12, I can give you guidance.*

Where possible, the teacher would directly tell students what they needed to do, making statements such as: *"You need to do more on this, expand on this", "You need two adaptations", "You've got to link in the environment".* She was careful not to compromise the criteria for assessment, as students themselves were required to select and process information and make their own links between environment and adaptation/modification.

*Week 10, term 1*

An observation from my voice recorder demonstrates the freedom students were accorded as they continued to work independently:

*Researcher observation: Student S is working upstairs with student F and student B. They are sitting at a table with another student from a different class who is working on a piece of art. The teacher and I move around visiting and checking in. Students are working everywhere. Jeff and Haeata are in the empty next-door laboratory. With one group, we talk about why it is so dry in Antarctica. With another group we talk about melting snow for drinking water on Everest. A group of four boys are working at a table outside in sun.*

In this same session, Haeata told me that student J and Tangaroa had gone to the Māori room to work.

*Haeata to researcher: There is a teacher there…Whaea…and she doesn't mind if other students come in and work.*

I commented to the teacher on this independent and mobile style of working. A different, teacher-led style of learning was visible through the glass and into the physics class next door. As we looked around at the science students quietly bent over their work, the teacher said to me:

> *It was funny, the other day, (teacher next door) was telling off his class, and I was thinking, 'Oh, I've got the best class'. But then, he was talking for more than an hour, so I'd probably start talking too.*

The teacher continued with her visits, focussed on ensuring students completed the task. She checked her list and ticked them off one by one. Students either had to share work on Google Docs or the teacher wanted to sight it.

*Week 11, term 1*

In the final week, everyone was trying to finish. Haeata and Tangaroa were trying to manage completion of the science internal and other assessment deadlines before going on a physical education camp.

> *Researcher to Haeata: Are you on the way to hand in on Thursday?*
>
> *Haeata: Nope...well…I'm going to have to…I guess…*
>
> *Researcher to Tangaroa: Will you be finished?*
>
> *Tangaroa: Probably not, I'll try. I have to finish (my other physical education internal) off, otherwise I can't go to camp.*
>
> *Researcher: Oh, so that's the main priority.*

Others needed individual teacher attention. Student S was reluctant to compete for that.

> *Researcher reflection: Student S sat down beside me. He had finished his assessment to Achieved level and wanted to ask the teacher what he could do to get up to Merit. The teacher was busy with student B. Student S was waiting, sitting quietly, doing nothing. He looked over at the teacher. He waited. I was*

*thinking he should ask her, but I think he wanted her to notice him. I prompted student S: 'Does the teacher know you need feedback? I think you should ask her'. So he did. And she gave him feedback. But would she have noticed him if he didn't ask? She was so busy.*

**Joseph**

Joseph was very keen on his topic and originally wanted to study three species of wolf. He was always busy on websites looking at information but seemed to be making little progress with the actual written assessment. I noticed he had about five lines written in pencil in his book, and the hand-in date was looming fast. The teacher suggested he focus on finishing one species well, then do more if time allowed. I listened to his discussion with the teacher about what he needed to do. It was obvious from this discussion that he had read, processed, and remembered information from many sources, but that he had little idea of how to structure this information into a written piece. To help him to capture this knowledge, I offered to turn on my voice recorder and let him tell me about his learning. I discussed with the teacher the possibility of running an oral assessment for Joseph. Allowances for oral assessments are made in achievement standards (NZQA, n.d.-b).

I interviewed Joseph about his topic and transcribed the interview for him, leaving my questions in the transcript so that the teacher, as marker, could monitor my questions. For fairness and validity my questions needed to stay within the boundaries of guidance permitted in achievement criteria and explanatory notes. Although there was little issue with establishing authenticity as Joseph spoke from memory, I sighted all websites and resources he had used in his learning.

Joseph was pleased with his eventual result of Merit and was surprised when he read his transcript at how much he knew and how articulate he was. He told me that he was expecting the transcript to only add up *"to half a page",* just like his written work. I suggested that talking and transcribing is a legitimate way of structuring knowledge to provide evidence of learning and told him that next time he could do an oral assessment again, but that he had to type the interview himself. He was very keen to do this.

### *7.2.4 Interpretive discussion for action research cycle one*

This evaluation and discussion focuses on student achievement in action cycle one in terms of NCEA results, before focussing on an analysis of how different elements of the learning environment constructed possibilities for different student and teacher identities. Other issues and outcomes associated with the personalisation of learning using context choice are also discussed, as are the influence of marking and moderation, and student motivation and achievement.

Of the 27 students in the class, 12 gained an Achieved grade and ten gained Merit. There were four Excellence grades and one DNS (Did Not Submit). The teacher demonstrated in a report to the school board that this result was above the national percentage statistics for student achievement in the standard.

In action cycle one, students could choose any context within a single level two internal earth science achievement standard. The level of inquiry could most closely be equated to a structured inquiry (Blanchard et al., 2010), because the task and methods of inquiry (in the form of an achievement standard requiring that students conduct a research investigation focussed on organisms' survival in extreme environments) were both chosen by the teacher. It could be argued that the action research intervention in cycle one did not move very far from much-critiqued, assessment-based, standard-led learning type practices (Absolum et al., 2009; Cowie et al., 2011; Hipkins, 2013; Hipkins & Vaughan, 2005; Hume & Coll, 2010; Jones & Buntting, 2013; Locke, 2005; Moeed, 2010). On the other hand, in conjunction with the NZC framework, it could be argued that the assessment standard anchored the learning to provide both scaffold (task and assessment criteria) and freedom (context choice) in a way similar to that described in the study by Bamberger and Tal (2007). A very small first step was taken towards personalising students' science programmes, as students were asked what they were *interested* in learning, with the grain size of context personalisation (within the prescribed task and standard) set at an individual level (Walkington & Bernacki, 2018).

There was a wide range of different context choices across the class, with some students choosing from a teacher-supplied list and others following their own interests. An independent *"I"* was apparent: *"I wanted to do (a particular topic)", "I wanted to learn more about…", "I'm interested in…", "I want to know…".* As students chose their own contexts, they were conceivably engaged in learning in which they had some interest and investment (Waldrip, Cox, & Jeong, 2014).

Learning was personalised in ways other than context choice. At work enabling wider personalised approaches and enabling students to take up different identities as diverse and self-managed learners was a complex and synergistic interplay between the four macro-level elements. For example, while Joseph used available digital technology to learn about his chosen context and personalise his presentation mode (digital voice recording), it was allowances within the NCEA assessment system that permitted the oral assessment. The flexible learning spaces were also an enabling factor. By their design the spaces allowed for ease of movement, and Joseph was able to choose to sit in the work space where he felt best able to concentrate, while maintaining contact with the teacher via Google Docs.

Across the different activities in cycle one, both teachers and students had access to and were able to take up different identities. The influence of the element of assessment was visible at the outset when the teacher emphasised that *"this (standard) is worth four credits."* Teacher and student actions from this point were focussed on the final goal of accrediting the learning. To accomplish this, the teacher took the lead in knowledge-building for the whole class in the early stages of this inquiry, acting as expert-knower and as curator of digital material. Similar to Hume and Coll's (2009) and Moeed's (2010) findings (see sections 3.4.6 and 4.2.3), the practice assessment amounted to training students to achieve in a specific NCEA standard. All students completed the task using the same context. Over this period the teacher took time to help and support some students, while determining that most students could gain an Achieved grade *"with a bit of herding".* Teacher and students were positioned by the NCEA assessment systems as needing to achieve a particular demonstration of learning/ knowing and they acted together to ensure this outcome.

It was noticeable that whole-class teaching ceased when students began making their own context choices and working individually on the *"actual"* assessment. The teacher moved into an expert-enabler role. While the teacher was supporting students to choose a context she gave up her 'knowledge holder' position, explicitly positioning herself as 'not-knowing' and *"open to suggestions".* She was careful to scaffold options and had curated a list for those who needed help in choosing. While the class worked on the actual assessment, the teacher balanced the giving of choices in where to learn with her position as taskmaster, keeping lists as she gave formative feedback and reminded students of deadlines. All of these actions were related to her duty to help students 'get through'. These actions are comparable with the findings of Ketelaar et al. (2013) who found that teachers' coaching roles became more significant as they guided students in project work (see also section 4.1.2).

Turning to other issues and outcomes, some literature argues that opportunities to personalise learning may disadvantage some students (Campbell et al., 2007; Leadbeater, 2006). In the data presented above, students who might not all be viewed as having a history of being successful science learners were seen accessing support from various sources as well as using their own life experiences to choose interesting, relevant contexts. As Seiler (2013) found (see section 4.2.1), students in this action cycle were choosing contexts based on knowledge gained from their interactions with technology (YouTube, movies, websites visited) and based on their prior learning in class. Twenty six out of 27 students gained credits for their work, therefore it would seem that personalising learning in a limited sense associated with context choice in structured inquiry, as used in this first cycle, did not disadvantage these students.

In this action cycle, moderation issues to do with fairness and consistency across different learning contexts were key teacher concerns. The teacher also had the responsibility of establishing authenticity of student work. During our discussions the teacher and I agreed that authenticity, and fairness and consistency in marking had been relatively easy to establish. Students were required to produce a log book. The teacher was able to track students' progress online through Google Docs via the revision history. The teacher could also provide feedback within this platform. The teacher was able to sight websites and have conversations with students as she circulated during science sessions. Time was available for this as the teacher was not delivering a structured lesson, as such. These conversations and website visits were important tools in developing teacher familiarity with the many contexts students were working within. Teacher knowledge of the diverse contexts students were working in enabled the teacher to judge the authenticity of student work and supported her ability to make fair and reliable judgements when assessing evidence of the learning that was presented for NCEA assessment.

The role of student choice as a motivational and achievement aid is well-reported (Høgheim & Reber, 2015; Patall et al., 2010; Seiler, 2013; Walkington & Bernacki, 2014). Seiler (2013) found that students who were not normally successful in science were more engaged when learning was connected to their lived experience. In this research, during action cycle one it was difficult to pinpoint motivational factors and establish causal links between choice and engagement. In saying this, the teacher in this study was of the opinion that the choice of contexts and the extended learning time given to complete the standard were key reasons that students achieved. My observations were that students on the whole were motivated through being given the responsibility of deciding upon and carrying out their own learning.

In summary, cycle one explored a limited model of personalisation using context choice within structured inquiry. The teacher enacted both traditional and less traditional identities, at first leading the learning in a structured way, before taking up the role of supportive expert-enabler. Student decisions in cycle one revolved around their interests within the frame provided, often supported by engagement with digital technologies, although pragmatism and ease also impacted the decision-making process for some students. While recognising that considerations of assessment for credits was a dominant influence, the teacher's intention in this cycle was to make learning about more than the assessment standard. Although scaffolding was necessary for some, in completing the standard, students had opportunity to enact independent learner identities which saw them motivated within their chosen contexts to progress to completion. This was made possible by the interaction of the affordances within flexible spaces, technology, curriculum, and assessment. Issues associated with moderation in marking were able to be mitigated. The next section reports on outcomes of action cycle two.

The next section reports on outcomes of action cycle two.

### 7.3 Cycle two: Developing questions within guided inquiry

This section presents data and findings from action cycle two which was conducted during term two (May and June 2017) and follows a similar format to cycle one. Firstly, the intervention is explained and secondly, I report on student choices and on aspects of student progress towards task completion. In cycle two I also report on an aspect of student questioning as part of the personalisation process. Finally, cycle two concludes with an evaluation and interpretive discussion.

### *7.3.1 Explaining the intervention*

Going into cycle two, the teacher and I were pursuing a vision of enabling a student-selected, tailored curriculum where each student pursued a science learning path they felt was relevant or useful to them. However, it was not possible at this stage to open choice completely. The teacher was focussed on her responsibility to students and parents to 'get them through' a science course with at least 14 credits. At this stage of the year, most students had seven credits (three credits from the microscope standard completed in the first part of term one, and four from the extreme environments standard completed during cycle one). As discussed in earlier chapters (e.g. sections 3.4.5, 3.4.6, 4.2.2, and 4.2.3), perceived risks or uncertainty associated with trialling new initiatives in high stakes assessment contexts often mean in practice that accountability concerns trump innovation.

In cycle one it was established that students enjoyed choosing from a wide range of contexts and that issues to do with the marking and moderation of student learning across a wide range of contexts were able to be mitigated. Cycle two sought to build on cycle one by personalising learning in terms of students' own questions within a single research investigation standard which was chosen by the teacher. The standard chosen was:

> AS91189 **Earth and Space Science 2.3**: Investigate geological processes in a New Zealand locality
> 4 credits Internal
> (NZQA, n.d.-e).

The extreme environment standard from cycle one was seen by the teacher as *"flowing in nicely"* to the geological processes standard in cycle two, which linked to curriculum level seven Planet Earth and Beyond achievement objective: Earth systems and interacting systems within the NZC (Ministry of Education, 2007a). At Achieved level, the task required students to identity rocks found in a chosen New Zealand locality and describe geological processes (the rock cycle, plate tectonics, and erosion are specified) that have formed the rocks and landforms in the locality.

Students were again permitted to choose a context for their learning, so in this case students could choose to study geological processes in any area of New Zealand. The teacher asked students to develop five investigatory questions about their chosen locality. By doing this, the teacher hoped to ignite students' interest in and thinking about the topic.

> *Teacher to researcher: (The questions) gives them more of a connection to it, within their chosen context.*

The teacher acknowledged that even this small step of 'asking students to ask questions', was a step outside normal practice. Normal practice would be for the teacher to structure the learning within the assessment and for all students in the class to study the same topic.

> *Teacher to researcher: Obviously I don't want to make it too hard, because the benchmark is to give the kids the questions, the research resources, even, then everyone does the same topic. So I don't want to disadvantage them.*

*Weeks 1-3, term 2*

As in cycle one, the focus at first was on learning the scientific concepts and vocabulary that students would need before embarking on the assessment. The teacher led the learning in these weeks and students stayed in the science area. Students completed structured cloze activities and worksheets. For example, they used information from resource sheets to complete diagrams showing the rock cycle and tectonic plate movement under the North and South Islands. The teacher was available, circulating to help where needed. The teacher preferred to teach key concepts by workshopping with separate groups, using the whiteboard tables to write notes and demonstrate concepts.

> *Teacher to researcher: I have to go through rocks, to each group, because then I'll know that they've done it. They need to understand about the rock cycle and the types of rocks.*

I was interested that the teacher preferred not to address the whole class and wondered if a whole-class delivery approach might be more efficient. I asked about this one morning.

> *Researcher to teacher: Do you ever collect the class together and say: 'Right, I'm doing this, on the board, once'?*

However, the teacher felt students were more engaged in small group teaching contexts, especially for afternoon sessions where she noticed students sometimes struggled with concentration. She therefore felt the extra time spent workshopping was worthwhile.

*Weeks 4-6, term 2*

The teacher remained focussed on providing students with the knowledge and skills they needed for the *"actual"* assessment.

> *Teacher to class at the beginning of week four: This is week four, and our actual assessment is on rock formations in certain areas of New Zealand, so, we need to move on from looking at tectonic plate processes that cause disasters to actually looking at types of rocks and how they might form, and then we can relate that to a particular area in New Zealand for the actual assessment.*

The teacher continued with her group-teaching approach. In week four the teacher was writing on a whiteboard table with a group of students clustered around her:

> *So, igneous rocks are the ones formed in and around volcanoes, so anything in the Taupo volcanic zone would include these type of rocks…*
>
> *…the magma gets blown out through an eruption, so it cools really quickly in the air, the rocks are often really light and filled with air bubbles, things like pumice, scoria…*

A formative or practise assessment task was offered. This task was also intended to extend students' knowledge of the topic. The teacher chose to focus on geological processes associated with the Christchurch earthquakes for the practise assessment for two reasons. The first was to *"leave the more interesting* *volcanoes and North Island areas for them (students) to choose".* The second reason was to do with scaffolding learning for the earth science external examination, as the practise task covered concepts which would be important in this.

> *Teacher to class: If you are thinking of doing the external, the Christchurch earthquake is more than likely to appear there.*

> AS91191 **Earth and Space Science 2.2**: Demonstrate understanding of extreme earth events
> 4 credits External
> (NZQA, n.d.-e).

The teacher was conscious of time, and students were given just three sessions to complete the practise assessment.

> *Teacher to class: So that we can get on to the real one.*

### *7.3.2 Making choices*

Students began deciding on their contexts for the *"real"* assessment in week six, and by week seven most were well underway. Students again chose contexts in different ways and for different reasons. Some students chose topics out of interest or by drawing on their own experiences. Some relied on the teacher to scaffold options and chose from the list of possibilities provided. Some students relied on combinations of these strategies to make their choice.

**Anahera**

Anahera was unsure which context to pick at first, then settled on Mount Tarawera and its surrounds.

> *Researcher to Anahera: What led you to that choice?*
>
> *Anahera: It was just on here (on the list of suggestions provided by the teacher) and I've heard about it.*

**Anshu**

Anshu chose Fiordland.

> *Anshu to researcher: I could do Tarawera as I did it in history but I wanted to learn something different.*

**Joseph**

Joseph chose White Island.

> *Researcher to Joseph: I'm interested to see how you go in this next topic. You had a lot of knowledge about wolves coming in to the last standard, as you had already read about them and been interested. What about this next standard?*
>
> *Joseph: Actually I'm knowledgeable about this topic too as Mum has done caving, and I've gone with her and read all these books and she's got a huge case of fossils and stuff.*

**Sophie**

Earlier in the year (week 2, term 2) Sophie had talked to me about her interest in earth science. When choosing her topic for the earth science standard, she told me her sister was studying earth science at university, and that she had access to rock samples. At first Sophie wanted to study Mount Tongariro.

> *Researcher: What interested you about Tongariro?*
>
> *Sophie: My sister's gone there, she told me things about her trip and the lakes and stuff and all that volcanic activity and I got really interested.*

However, when it came to completion of the assessment in week six, Sophie changed her mind and chose the Auckland volcanic field.

> *Researcher: Whereabouts have you seen and heard about the Auckland volcanic field?*
>
> *Sophie: I just know that Mt Eden is one of them and I've seen a picture of this…of this crater, like, going down (gestures). And…I can't remember…One Tree Hill or something like that? And I'm just quite interested in it…I've been to Auckland, but I never knew it was volcanoes.*

Amongst the rest of the class, White Island was a popular choice because:

- *just how close it is to us, and it's volcanic* (Student M)
- *local area and I know it* (Student S)
- *cos it looks like the easiest one* (Student J2)

- *it's the only one I know* (Student F)
- *I did a helicopter tour out there* (Student J3)

### *7.3.3 Student progress to task completion*

*Weeks 7-9, term 2*

There was plenty of time available to complete the assessment task between weeks seven and nine. This was necessary because many students were in and out of class as they engaged in other aspects of school life. As well as the usual days for Trades Academy, during this term various groups of students were busy organising the school ball or involved in the school production.

The teacher would often begin the session with a brief reminder or outline of where students should be headed. Her initial focus was on helping all students to get to the standard of Achieved. In the middle of week eight, the teacher addressed the whole class:

> *If you're at a point where you haven't really done a lot, there's two things you need to do to get it started. The first is pick an area, describe where it is, so White Island is found….*
>
> *If you can mention where it is in relation to tectonic plates, that would be a good thing. So White Island, it's in the subduction zone, subduction is where the Pacific plate dives underneath the Australian Plate over to the side of the North Island, so if you can explain about that, that would be good, and then pick your two rocks and explain to me what type of rock it is and briefly how it forms. That will get you an Achieved, at the very least.*

As students were working independently they were able to move across spaces. Students were permitted to work in the upstairs commons or to sit outside. They were permitted by the biology teacher to sit in with her students provided they did not distract. However, students were not permitted to enter the physics space, which operated as a separate class through the closed glass slider.

Not all students used all class time available to focus on assessment or task-related ends. Digital devices were used for learning, but constant access to games proved distracting for some. During these weeks I approached students who seemed to be off-task. In week seven, I talked with two boys (student L and student F) who were sitting together, busy playing games on their devices.

> *Researcher: So, tell me about this, then.*
>
> *Student L: I'm playing Clash of the Clans.*
>
> *Researcher: You've got stuff you could go on with, right now?*
>
> *Student L (absorbed in his game): Mmmmnn hmmm….*
>
> *Researcher: So what is it that's stopping you from moving on?*
>
> *Student F interjects: Addiction! (We all laugh)*
>
> *Student L: It's like, the bell doesn't go until 10.30am, (it is 9.30am) so I can spend 20 minutes then get to work….and still get heaps of work done.*

In week eight I noticed student J playing games on his laptop in the biology area.

> *Researcher to student J: What's this called?*
>
> *Student J: Indestructible Wall (He carries on playing).*

Back in the science classroom, I approached another student who I assumed was also was off-task. He was, but in a different way.

> *Researcher to student S: What are you looking at?*
>
> *Student S: I'm looking at stuff to do with welding, cos recently, like, I burnt my hands (he shows me his hands) at Polytech (at Trades Academy). I didn't know that it gives off UV and stuff and so I was welding for a whole day and my hands got sunburnt…I didn't know what it was…I thought I got sunburnt in winter…it's my fault…they say wear gloves.*

**Anshu, Anahera, and Taabah**

Most students worked steadily with the teacher's support to complete their achievement standard. Some began to use extra time to begin study for the external earth science examination. The first opportunity they would get to formally assess their knowledge would be in the mock examinations, held in week eight of term three. Cycle three reports on student actions and progress towards this external. The following brief excerpts portray issues and approaches during cycle two for a few of the target students.

As the teacher predicted, selecting and processing relevant scientific information for this standard proved to be challenging for some students. The teacher was busy in these weeks supporting students to find websites which contained relevant, accessible information. There were many websites and resources available, but not all were navigable.

In week seven I approached Anshu, Anahera, and Taabah, who were sitting at a table together.

> *Researcher to group: How are you going?*
>
> *Taabah: We're trying to find information – it's hard.*
>
> *Researcher: What's hard?*
>
> *Taabah: "…" (Taabah doesn't say anything but gestures at the web page she has found).*

Although the information was relevant to the investigation, she was trying to sift through it and make sense of heavily scientific vocabulary. I suggested the group unpick key terms together by researching each new word separately (for example, composite volcano, stratovolcano) before trying to extract information for their standard.

**Jeff**

While some students struggled with language and literacy, Jeff finished early, at the beginning of week eight.

> *Researcher: What made it possible for you to finish early?*
>
> *Jeff: I just did my work, got on with it. I chipped away at it, I did some at home. It was quite easy after doing the practice.*

Jeff decided to use the extra time to work on the microscope standard which he did not get to complete earlier in the year, having swapped into the science class from physics. There was a structured workbook available which he was going to work through by himself. Jeff completed the standard within three sessions, gaining Merit.

**Joseph**

Joseph was very keen to do an oral assessment again. This time we both felt more confident with the process. When he was ready for assessment in week nine, I interviewed him again, but this time I left him to type his own transcript ready for hand-in. During the interview, while he was articulate about many aspects of rocks and rock formation to do with his topic of White Island, I realised he would not achieve the standard as he did not know enough about tectonic processes. The criteria for the standard was specific. At Achieved level Joseph was required to "describe the rock cycle processes that have formed the types of rocks in the locality" (NZQA, n.d.-e).

> *Researcher to Joseph after the interview: Where there any parts of the interview where you felt uncomfortable?*
>
> *Joseph: Yep.*
>
> *Researcher: Which parts?*
>
> *Joseph: The tectonic plates.*
>
> *Researcher: Well, there's nothing stopping you googling that and finding some more information to pad out that part before you hand it in.*

Joseph subsequently did this and gained an Achieved grade.

### *7.3.4 Choices and questions*

Although the intention was for students to develop their own research questions, the consequence of being tightly focussed on a structured, pre-set task (the standard), was that students formed narrow, low-level questions that converged on the criteria in the standard. This instrumental approach arguably facilitated learning within the task but did little to extend or personalise learning. My hunch was that students did little more than convert the guidance given in the assessment criteria and explanatory notes into question form. Two examples of student-developed questions which led them towards meeting the criteria in the standard are listed below:

**Jeff**

- Where is White Island situated?
- What tectonic plates is NZ on?

- How is igneous rock formed?
- How is scoria formed?
- How is andesite formed?
- How was White Island formed?

**Anshu**

- Where is Fiordland located in NZ?
- What kind of rocks are found in Fiordland?
- What processes in the rock cycle have formed these rocks?
- How was Fiordland created?
- Which tectonic plates does Fiordland sit on?

However, while positioning students as question-askers, and perhaps because of the focus on questions in this cycle, I noticed students were wondering and asking questions more widely and beyond the standard as they engaged with the learning. In contrast to the instrumental questions were curious questions which might lead students on a more self-directed path to investigatory learning. I share one example below.

**Tangaroa**

I came across Tangaroa in week eight, looking at a picture of White Island showing ash, sediment, and sulphur from a recent minor eruption floating away on the sea current, discolouring the ocean.

> *Tangaroa (pointing to the discoloured water): What's all this, Miss?*
>
> *Researcher: Sulphur? And ash? There might have been a little eruption and all that is leaking out into the sea.*
>
> *Tangaroa: That's cool. Does it affect the fish?*

The discussion that followed was about wondering. It might, I said, in the immediate area, but as it moves and spreads, maybe the pollutant introduced from the eruption will be diluted. At this moment we diverged a little – I had wrongly assumed 'dilute' would be part of his vocabulary.

> *Tangaroa: What's dilute?*

*Researcher: It's like a little bit of stuff in a lot of water. Like if you put a drop of Coca Cola into a glass of water.*

*Tangaroa: Like if you put just a little bit of Raro in.*

*Researcher: Yeah, that's dilute.*

We circled back to his original question about the fish. The question could be explored, but not for credit. I encouraged him to write his curious question down but was quick to remind him about what he needed for the standard.

*Researcher: It's an interesting question. Find out a bit about it and add it into what you're doing. You know how (the teacher) wanted you to develop your own questions – make that a question as well, why not? But make sure you answer these other ones… (showing him the check-sheet of what he needed to do to complete the standard).*

*Tangaroa: I just have to write it down otherwise I'll forget.*

**Sophie**

Sophie was interested in the Auckland volcanoes. She had never been to any of the volcanoes in Auckland but wondered: *"How the volcanoes pop up and why Auckland is actually built on it, and why they're not being more careful, cos in theory any minute… (they could blow)".*

Other openings for curious questions came as students were deciding on contexts or working to complete the standard. One student (student S) wanted to study gold mining on the Coromandel Peninsula because he had lived in the area. My conversation with this student was about whether gold is a rock (it is a mineral/ore). As the achievement standard specifies that students study rocks and rock types, I refocussed the student on rocks. Another student wanted to know how a large eruption from White Island would affect us. He did not pursue this question, as it was not part of the criteria for the standard (Student M).

### *7.3.5 Interpretive discussion for action research cycle two*

This evaluation and discussion begins with a statement of achievement outcomes as NCEA results for action cycle two. Next an analysis of teacher and student positions and identities focusses on elements of assessment and digital technology, and the impact of these on how students asked inquiry questions and progressed in their learning.

The overall results of 27 students who attempted the standard were: 18 students at Achieved level, four at Merit, three at Excellence, and two DNS. These results again were higher than national averages for percentages of students gaining Achieved, and similar to national averages at Merit and Excellence level.

The achievement standard chosen for action cycle two was an internal research investigation. Context choices were limited to rocks in a New Zealand locality and this impacted the extent and nature of context personalisation able to be offered (Walkington & Bernacki, 2018). The explanatory notes for achievement criteria defined *"investigate geological processes"* as identifying and describing rock types, describing plate tectonics, the rock cycle, and erosion processes (NZQA, n.d.-e). As such, students were perhaps not positioned as 'investigators' as much as they were consumers of a specified knowledge base. Therefore, although students were asked to develop their own questions in this cycle along the lines of a guided inquiry, the task that students actually undertook was more aligned with the definition of structured inquiry (Blanchard et al., 2010), which stipulates both topic and methods of inquiry. The tendency to focus on science concepts and declarative knowledge in a biology internal investigative achievement standard was likewise noted by Johnston et al. (2017).

The teacher was committed to ensuring students attained an Achieved grade, *"at the very least".* Students needed to develop understanding and be able to communicate specific science knowledge. To achieve this, the teacher needed to know that every individual had *"done rocks and understood".* She therefore played an important role in presenting information and scaffolding, building, and extending students' knowledge as she prepared them to complete their formal assessment. To do this, the teacher preferred to workshop with separate groups. Therefore, the teacher was acting as a traditional teacher-as-expert to deliver foundational knowledge (Carlone et al., 2010; Melville & Bartley, 2013), but in a slightly different way. Students had no choice about attending these workshops but by her physical proximity and positioning as part of the learning group, the teacher considered she was able to engage students more effectively than by using a whole-class delivery approach. Another aspect of the teacher's role in supporting achievement was to curate appropriate resources and provide guidance to students as they accessed and made sense of information (Ministry of Education, n.d.-b).

One of the differences between cycle one and two was the requirement for students to develop their own questions. Students developed some rich, investigatory questions, however, the actual questions students asked and answered were directed by the requirements in the standard and the time frame permitted. It was not possible for students to be enquirers in a completely open way. The process of formulating inquiry questions perhaps facilitated deeper interest and greater investment by students in their topic (Bevins & Price, 2016; Furtak et al., 2012; Minner, Levy, & Century, 2010). In spite of this, the impact of the prescriptive criteria in this standard was apparent as students funnelled their learning towards presenting specific facts in a specific way. Hipkins and Vaughan (2005) also describe instances in some NCEA assessment contexts where rather than being curious about wider learning, students ask: “Is it assessed”?

Technology was an enabler in this cycle as it allowed students to search for information, but comments from some students indicated that the dense scientific information found was difficult to engage with. Again, Joseph used digital technology to capture and communicate his knowledge about earth science in a way that he could work with. However, making use of technology for learning relies on students taking up self-managed, motivated identities, and not being reliant on the teacher’s exhortations to work at every turn. In cycle two the distractions that technology supplied were noticeable. Science learning was in constant competition with games, social media, and other enjoyable technology-based activities. Many similar instances of negative effects due to distraction and off-task behaviour associated with the use of digital technologies have been previously discussed in literature (Aagaard, 2015; Dobler, 2015; Kay et al., 2017; Sullivan et al., 2014).

In summary, cycle two sought to build on cycle one by developing learner competence to ask questions in a guided inquiry where a single achievement standard was chosen by the teacher. Certain aspects of knowledge within the field of geological processes were stipulated in this achievement standard. While this ensured students engaged with the specified knowledge, it also impacted the way students asked and answered questions and resulted in students being positioned not as investigators of their own curious inquiry questions but as consumers of a specified knowledge base in a structured inquiry. It also impacted the way the teacher approached her tasks in scaffold and support of student learning.

Towards the end of term two, as the geological processes standard was completed and handed in, the teacher began talking with the class about their next steps. The plan for the next action research cycle in term three was to open learning up to permit students to choose their path. Chapter eight presents outcomes from action cycle three.

# Chapter eight: Phase two action research cycle three

This chapter presents data and findings from the third cycle of action research. This was conducted over a four-month period (July – October 2017), beginning in the two last weeks of term two, for the whole of term three, and into the first two weeks of term four.

In cycle three, steps were taken to further unpack what it means to personalise science learning. Section 8.1 gives an account of the beginning stages of cycle three. It begins with a brief description of the intervention in terms of four different options that were available to students. Next in section 8.2, data is presented to show how the teacher informed students of options and supported them in their decision-making. Data shows how and why students made choices and summarises their initial choices. The section concludes with an interpretive discussion of the choices offered and students' positioning as choice-makers.

Section 8.3 presents data focussed on students' learning paths. It illustrates student actions, interactions, progress, and decisions as they worked towards their self-selected goals within the four options. An interpretive discussion concludes the data presentation section for each option. This presents an evaluation of NCEA achievement outcomes and a reflection on teacher and student actions and identities as personalised learners.

Finally, section 8.4 summarises student choices and achievement outcomes for cycle three and details the focus students' achievements and choices throughout the year. This section ends by looking forward, to describe the teacher's plans post-action research.

## 8.1 Cycle three: Personalising science learning by scaffolding a range of choices in science inquiry

### *8.1.1 Explaining the intervention*

Compared with cycles one and two, in cycle three students were offered a larger number of options and higher degree of flexibility in their learning. This was possible because towards the end of term two most students (23 out of 27) had 11 credits out of a course minimum of 14 and so at this stage the teacher felt comfortable with giving the class more choice. Students were told the plan for term three was to *"open the learning right up"* and permit students to choose their path. Students were asked to think about what they might be interested in doing, what they might need in terms of learning and credentials that might complement their learning in other subjects, and what might be most useful to them for their future plans. The teacher envisioned students would complete at least one standard during term three.

The options students had to choose from were explained at the end of term two, as students were finishing their geological processes standard and well before they would be required to decide upon a learning path. Options were explained to students in the following order:

| | |
|---|---|
| Option one: | Students could formulate their own science question and pursue a self-directed, open inquiry. |
| Option two: | Students could choose to work within any discipline and any achievement standard from the level two matrix. Similar to cycles one and two, students could choose also their own context in the investigative achievement standards. |
| Option three: | Students could opt to work towards an external earth science standard should they be aiming for subject endorsement (this option would be completed alongside and in addition to options one, two or four). |
| Option four: | Students could choose to complete a more traditional, teacher-directed, level two earth science achievement standard. This was a practical investigation standard, focussed on methods for cleaning up oil spills. |

## 8.2 Making choices

### *8.2.1 Option one: Open inquiry*

The first option of open inquiry-based learning was introduced to the whole class in week nine of term two, and before other options were introduced. Students were told they could choose an area of interest for investigation, formulate a question/s, and carry out an investigation. The teacher told students that she would attempt to find standards from the level two science matrix with achievement criteria which matched or were congruent with their investigation so that their learning could be assessed for NCEA. Therefore, in this option, students' interests and wonderings were permitted to direct what happened, with their learning and assessment evolving from there. Following the teacher's introduction of this option, I talked with individuals to ascertain who might be interested is this option, and if so, in what possible areas.

Even those who expressed an interest appeared tentative about taking up this option. For instance, student L was interested in how skateboard tricks can be done and *"how they can be done better"* but was also concerned with credits. This student wanted an Excellence or Merit endorsement.

> *Researcher to student L: Do you have any ideas about what you could or would do?*
>
> *Student L: We get to come up with our own project ourself? And it has to relate to science?.......I'd go for skateboarding and physics and look at the way physics is applied to the skateboard. But it depends how many credits. It would need to be a decent amount of credits.*
>
> *Researcher: What are you wondering about?*
>
> *Student L: I wonder how the skateboard actually works, like, when you're in the motion of a trick, cos some people have said that…skateboarding doesn't always follow the laws of physics…there's studies on it, like how it defies the rules of physics…like… (and he gets out a miniature toy skateboard and shows me what the skateboard does) a tray flip like this… So, it's like … (and he shows me the whole movement again) and that's supposed to be impossible in physics terms.*

When I next talked with this student early in term three, he had chosen to work with the oil spill group (option four) because he needed a Merit endorsement.

> *Researcher: Why did you choose the oil spill standard? You wondered about skateboarding….?*
>
> *Student L: I needed the endorsement, Merit endorsement.*

Other students expressed a similar credit-focussed view when asked: *"Are you interested in the idea of open inquiry-based learning?"*

> *Student F: No, no credits.*

*Researcher: If there were credits attached?*

*Student F: Not really, (it would be) just more work.*

Student N was unsure: *"Um…not sure…if it gets me credits, I guess…it depends, like, will it get you anything, the same quality credits, would it get you the same amount of credits?"* Student S also explained, *"I'm not really interested, I'd rather get something worth credits".* When I asked student S if he would be interested if he could be credentialed for the work, he replied that maybe he would, but he *"had no ideas about what to do".*

Taabah when asked was also pragmatic and focussed on expedience and gaining credits.

*Taabah to researcher: Not sure, depends how many credits, like some internals, you have to do a lot of work on and (the internal) only offers you two (credits), so like…don't want to do that…*

Other students had interests which did not align with a science inquiry. For example, student M2 had already achieved the minimum 60 credits for NCEA level two and was waiting to go to Tourism school. In another example, my question to student M1 which was asked within a science frame, received an unexpected answer:

*Researcher: If you could study anything at all, what would you do?*

*Student M1 (with no hesitation): Real Estate.*

In the end, of the 27 students, five students chose to pursue their own science questions. Their questions are introduced below.

***Tangaroa:*** Tangaroa had an interesting idea for an open inquiry. I include the full conversation below to demonstrate his creativity in blending cultural and science knowledge to form a question and the tentative way in which he shared his question with me.

*Researcher: Did the idea of project-based learning interest you?*

*Tangaroa: Yep, yep.*

*Researcher: Did any particular areas come to mind?*

*Tangaroa: Um…. (he is silent for a full ten seconds) … it is kind of to do with like…I was thinking maybe, like…there's a lot of Māori stories about how things have happened, so like…and if there was a different explanation…*

*Researcher: So, merging science and Māori explanations for how things have happened? Have you got any particular stories in mind?*

*Tangaroa: I don't know if this is relevant but…*

*Researcher: It can be anything…*

*Tangaroa: Māoris used to reproduce or mate with the same blood and there was like, no deformities…so they didn't have…they didn't come out like, disabled …I don't know how it happens…but nowadays…*

*Researcher: So, investigating a story that's there…*

*Tangaroa:* **Why** *is it there…*

***Joseph, Haeata, and student J:*** Joseph formed an idea for a project around 'the science of attraction'.

*Joseph to researcher: I want to try and do one about attraction between genders… and like… well… what the attraction is.*

Haeata and student J were interested in joining with Joseph to work as a group.

***Jeff:*** Jeff decided to inquire into the physics of a gunshot recoil. His plan was to look at the mechanisms within a firearm and the forces that are acting when a gun *"kicks back"*.

### *8.2.2 Option two: Self-selected structured inquiry*

Against the foregrounded option one of open inquiry in which student choices were made independent of, or outside of the matrix of level two achievement standards, in the last week of term two (week 10) the teacher also 'threw open the matrix' for students. This was the second option presented to students. They were offered the option of choosing an area of study from all level two standards that were available. The teacher explained that they could use the science disciplines themselves as a basis for making a choice within an area of personal interest. They could complete a research-based or investigation-based internal in any of the level two chemistry, biology, earth science, or physics standards.

The teacher distributed copies of the level two science matrix to students (Appendix B). She prefaced the idea of open choice within the matrix saying:

> *Teacher to class: Basically, you've got the entire matrix to play with. I can find tasks for whatever you want.*

She then talked individuals and groups through the many options in detail.

> *Teacher to Sophie, Taabah, Anshu, and Anahera: Can you have a look at that matrix? I'm going to talk with you more about it so that we can come up with a plan.*

Some students were able to decide fairly quickly on a path while some were not. For students who were unsure, the teacher offered concrete options to see which appealed. For example, she explained the possibilities for the chemistry technology standard to a group:

> AS91163 **Chemistry 2.3:** Demonstrate understanding of the chemistry used in the development of a current technology
> 3 credits Internal
> (NZQA, n.d.-e).

> *Teacher to group: ...anything from polymers and plastics right through to how drugs are modified from one form to another, how steroids are isolated from hormones your body makes, contraceptives, things like that... things like opiates, like heroin, codeine, morphine, antibiotics. You have to look at the chemical structure and how it's changed, how that molecule works.*

In the same lesson, the teacher listed tasks and sample contexts for the earth and space validity issue standard for a group of students, including student J3. She piqued his interest by giving him an opportunity to express his opinion about science ideas as they are sometimes presented in news media.

AS91188 **Earth and Space Science 2.2:** Examine an earth and space science issue and the validity of the information communicated to the public

4 credits Internal

(NZQA, n.d.-e).

*Teacher to student J3: …rubbish in the ocean, climate change, should Pluto be a planet. There's also one about what killed the dinosaurs.*

*Student J3: A big rock! (There is a group of us at the table listening and we all laugh).*

*Teacher: Well, you've got to look at the science. For example, there's things that come out in the news- (student J3 interrupts).*

*Student J3: I don't trust the news.*

*Teacher: Exactly – that's exactly what this standard's about. Analysing information given to the public.*

*Student J3: They just give you what people want to hear.*

*Teacher: Yeah, well it's clickbait, isn't it, they make it look more sensational than it is. So that's what that one is, you need to have three sources and analyse the science… give an opinion.*

*Student J3: Yeah, probably that one.*

The teacher explained the possibilities for the biological validity standard to another group:

AS91154 **Biology 2.2:** Analyse the biological validity of information presented to the public

3 credits Internal

(NZQA, n.d.-e).

*Teacher to group: …caged hens vs factory farms - HPV vaccines - which is what the biology class is doing. You analyse the information and decide whether it's valid information, scientific information, and what you think about it, so it's more of a research one…*

Anshu chose this option. She wanted to study the discipline of biology and also enjoyed *"doing research and writing it up."* Anshu inquired of the teacher: *"Are there any report writing ones?"* The teacher pointed her to the biology validity standard. Anshu responded that she wanted to *"have a think about what is in the news"* before choosing a topic. When I next talked with her early in term three she had chosen the HPV vaccine as her context.

Sophie also was interested in biology and wanted to be seen as having *"been bio".* Sophie chose the biology practical investigation.

> AS91153 **Biology 2.1:** Carry out a practical investigation in a biology context, with supervision
> 4 credits Internal
> (NZQA, n.d.-e).

She had a clear rationale for the choices she was making.

> *Sophie to researcher: I want some bio credits. I've already got three, but I need some more because I want to go into Vet Nursing and want them rather than (other) science credits. (The teacher) said it would have been fine having my earth science credits because it's all investigation and practicals but I really wanted some of those bio credits to say I have been bio.*

Similarly, student B, who was not permitted entry into level two biology as she had not achieved in the level one external, chose a biology internal, rationalising this focus as gaining biology credits on the path to midwifery training.

Taabah did not want to take on an open inquiry, however, she was interested in choosing her own science discipline. She was thinking about working in a biology context because she had been *"good at biology"* in level one. She initially chose to work on the validity of a biological issue standard in the context of the HPV vaccine because:

> *Taabah to researcher: I already know some facts about it because when we had it (the vaccine) we got talked to about it. And it was really painful.*

However, her earlier concern with ease and expediency in gaining credits, when combined with a suggestion from the teacher, changed her mind. The teacher thought Taabah might like to work on the earth science extreme environment standard as she had missed this standard, arriving in the class from another school in term two.

> *Taabah to researcher: (The teacher) says I should do this first because it's worth more credits than the other one and she says it's easier than the vaccine one.*

In total, five students chose the second option of contextualising their learning within a self-chosen science discipline and achievement standard, mainly for reasons of interest and enjoyment, and because they saw the learning as relevant to their futures.

### *8.2.3 Option three: An external examination as an additional choice*

A third option that students were offered was to begin to study for the earth science external examination to be held at the end of the year. They would need to do this alongside and in addition to completing one of the other options.

Some students I spoke to about this option were non-committal and planned to study for the external only if they were low on credits.

> *Researcher to student M1: Were you thinking about doing the external for this course?*
>
> *Student M1: If I don't have enough credits I probably will but…otherwise nah….*

Student N told me his decision *"depends how much credits I've got, I'm gonna do it if I need it to pass the level two."* Student S thought he *"might enter the external, it just depends if I need credits."* Many students in the class (e.g. student J, J2, Anshu) did not want to pursue course endorsement and preferred to gain credits using internal achievement standards only. Student J explained: *"As long as I pass I'm happy."* Others may have been unwilling to risk failure, which they had experienced in level one. Student O told me: *"I passed level one, but I didn't pass my science externals."*

Student L was treating all credits, including externals, as insurance:

> *Researcher to student L: You were one of the ones who was thinking about studying for the external as well?*
>
> *Student L: I just want as many credits as I can…opportunities. Like in maths, I'm doing Maths Applied, but I'm also taking on calculus credits. Even if I fail them, I want to know I have the opportunity to get them. So, I'm just taking on as many credits as I can.*

As external credits are necessary to gain a subject endorsement (NZQA, n.d.-d), the six students who wanted endorsement began to learn for the earth science external examination during term three. They were Taabah, Sophie, Jeff, Anahera, student J3, and student L.

### ***8.2.4 Option four: Guided inquiry***

Earlier in the year the teacher predicted many students would need targeted support if options for learning were opened up.

> *Teacher (week 5, term 2): I love the idea of personalising learning, but I look at these guys (indicates towards two groups sitting at tables along one side of the room) and I think, unless they're forced to do something…can you imagine? They would be able to pick something, but to drive themselves in this way of learning… They'd have to be quite independent, they'd have to have really good mentors. Because I could see some kids working for an entire term and getting nothing and then we'd get blowback from parents.*

The fourth option offered to students was to continue on the earth science track and join a group working on a more traditional, teacher selected, teacher-directed, internal earth science practical investigation. Students would complete an investigation into best methods for cleaning up oil spills. The task was pre-structured, and equipment was pre-organised.

The associated standard was:

AS91187 **Earth and Space Science 2.1:** Carry out a practical earth and space science investigation
4 credits Internal
(NZQA, n.d.-e).

Seventeen of the 27 students initially opted for the oil spill practical. When I asked, students gave me various rationales for opting into this standard. Student F thought he would *"probably do the earth science practical…it sounds easier."* Student M1 wanted to do something that included practical work: *"It's just something to get hands on, cos all of our last stuff has just been writing, so I just chose something a little bit interesting."* The clearly structured path appealed to Anahera: *"I've just got so much else on, I wanted something easy that I could do at school."* The idea of working in a group attracted student S: *"It kind of sounded the easiest and with lots of people doing it there'll be more information and stuff about it…"*

This fourth option, where everyone carried out the same task and everyone progressed as a group appealed to many students. In contrast, the context of oil spills did not interest student J3.

> *Teacher to student J3: …there's the practical (option) where you plan and carry out a practical to do with earth and space science.*
>
> *Student J3: What do you do for that?*
>
> *Teacher: I've got one on oil spills, what's the best material to mop up an oil spill from the beach…*
>
> *Student J3: Why would I want to know that? I'd probably rather do a researchy one.*

### *8.2.5 A summary of option choices*

Most students (17 out of 27) opted for the teacher-structured task and to complete the oil spill practical (option four). Five students chose to work within a self-selected standard and a self-selected science discipline (option two). Five students devised questions for their own project or inquiry-based work (option one). As the term progressed, one student from the open inquiry group changed options to complete the oil spill practical. Six students also worked concurrently towards the external earth science examination (option three).

Table 2 below summarises student choices at the start of term three.

***Table 2: Overall student choices***

| *Option number* | *Option type* | *Achievement standard attempted* | *Number of students (27 in total as at end of term 2)* |
|---|---|---|---|
| Option one | Open inquiry | Physics 2.2: Demonstrate understanding of physics relevant to a selected context | One student |
| | | Biology 2.1: Carry out a practical investigation in a biology context, with supervision | Three students as one group |
| | | Biology 3.2: Integrate biological knowledge to develop an informed response to a socio-scientific issue | One student |
| Option two | Self-selected structured inquiry | ESS 2.4: Investigate how organisms survive in an extreme environment | One student |
| | | Biology 2.2: Analyse the biological validity of information presented to the public | One student |
| | | Biology 2.3: Demonstrate understanding of adaptation of plants or animals to their way of life | One student |
| | | Biology 2.1: Carry out a practical investigation in a biology context, with supervision | One student |
| | | ESS 2.2: Examine an earth and space science issue and the validity of the information communicated to the public | One student |
| Option three | External examination | ESS 2.5: Demonstrate understanding of the causes of extreme earth events in New Zealand | Six students (as well as completing another standard) |
| Option four | Guided inquiry | ESS 2.1: Carry out a practical earth and space science investigation | 17 students |

### *8.2.6 Interpretive discussion*

In this discussion I focus on teacher and student actions and identities associated with the offering and choosing from a range of options which supported students to personalise their science learning path.

Prain et al. (2013) question the extent to which students might be able to successfully accomplish the complex process of making "personal, informed choices about what they learn, how they learn, why they learn, when and where they learn, and whom they learn with or from" (p. 658). In cycle three the teacher deemed it safe in terms of student experience and assessment credit numbers to open up learning choices. Her actions in setting out choices for students were consistent with Katz and Assor's (2007) claim that learner competence to make choices must be developed and supported. They were consistent with Yonezawa and Jones's (2007) suggestion that in personalised environments it is the teacher's duty to provide support by creating opportunities within which students can make choices.

The choices the teacher offered included open and self-selected structured inquiries, and a guided inquiry. This range of option choices allowed and required the teacher to provide different levels and kinds of scaffolding for student autonomy in the personalised environment (Patall et al., 2010). For example, the teacher scaffolded student autonomy in making context choices as part of self-selected structured inquiry when she used her broad-reaching knowledge of contexts within each discipline in conjunction with her knowledge of NCEA science achievement standards to suggest a possible focus for student science inquiries.

The element of assessment was dominant in both enabling and constraining the options the teacher offered and the choices students made. Mirroring Wortham and Jackson's (2008) account of student identity as a socially constructed "assessed statistic" (p. 115) (see section 2.4), for many students in this action research their recognisability as competent and successful came from achieving credits in NCEA. This agenda was evident in student comments about their choices: some students expressed a concern with gaining credits, others worried about having to complete extra work, or were unsure of what they might need to do to achieve as part of a self-designed open inquiry. A striking example of this was student L, who although enthused about his skateboard idea, chose the oil spill standard as he said he *"needed a Merit endorsement".* Overall, the distribution of student choice indicates that experiencing themselves as the type of learner who might ask and answer their own science questions was seen as risky. As discussed in section 4.1.2, if students are frequently positioned as followers of teacher-led learning and positioned as players in a game involving strategies directed mainly at achieving credits, they may find it challenging to reposition themselves and accept the right to "ask questions, to discuss, to imagine how things could be different" (Claxton, 2007, p. 119).

Similarly, the teacher recognised that for some students, undertaking an open or self-selected structured inquiry might be challenging. She speculated that unless some of her students were *"forced"* to do something they might *"work for an entire term and get nothing"* in terms of NCEA credits. It was for this reason the teacher offered the teacher-directed guided inquiry oil spill option in addition to the more personalised choice options of self-selected structured and open inquiry. The teacher's comments positioned her as accountable to students and their parents for students' success in a manner similar to that identified by others (Gillon & Stotter, 2012; Wylie & Bonne, 2016).

Five students positioned themselves as able and willing to choose to pursue an open inquiry of their own design. Katz and Assor (2007) and Ruddock (2007) have argued that students value opportunities to make choices in their learning (see section 4.1.2) and taking up the option of open inquiry allowed students to learn about an aspect of science that interested them. On the other hand, the prospect of making a choice gave student J3 the power to openly question why he *should* be interested in knowing about methods for cleaning oil spills.

In summing up, this action cycle opened up a number of choices and the opportunity for students to personalise their science learning. The distribution of students choosing the different options, especially the open inquiry (option one) is indicative of challenges for students in taking up identities which align with personalised learning ideals in high stakes assessment environments. The next section describes how students' choices played out.

## 8.3 Cycle three: Students' progress through their inquiries

This section presents data which details how students went about their learning and what they achieved within their chosen options. After a passage which discusses the teacher's role, I present and comment on happenings within the oil spill group (option four), as the largest number of students chose this option. I next show the thoughts, actions and decisions of three focus students from the group who self-selected their standards (option two). I then outline what happened for the six students who worked towards the earth science external examination (option three). Finally, I report on happenings for students in the open inquiry group (option one). Each of these subsections are followed by an interpretive discussion.

### *8.3.1 The teacher's role: Directing students and space*

Throughout term three the teacher worked hard to balance the fluidity that the flexible spaces enabled with her responsibility to ensure everyone remained on track. There was very little whole class teaching. Instead students had large amounts of unstructured time, and it was up to them (with the teacher's support and direction) to make sound use of it. Sessions often began with everyone gathered together for brief teacher-led focussing instructions before students dispersed to carry out their individual tasks. Some students went to see other teachers, others worked on tables outside. If permission was given, some students went to the upstairs commons, where there were fewer students and it was easier to find quiet space. Some chose to work in the adjacent biology area. There, they would sit at an empty table or on the floor, or even amongst biology students who were working with their own teacher.

Students were permitted freedom to work where and with whom they chose, but trust to work independently and anywhere needed to be earned. Sometimes students were not permitted to *"wander off"* upstairs to work. For instance, in week two, term three, the teacher briefed the class:

> *Teacher to class: I don't want anyone wandering upstairs this block. You're staying downstairs where I can find you. Today what I'd like to do is check in with the practical people. (The teacher has set this group up sitting together at two tables). I understand some of you are not 100% sure about what to do for*

*this booklet. The rest of you have things to get on with ... (...) ... I've booked computers so you will be able to have those ...*

Interestingly, there was difference in the teacher's treatment of students who opted for the structured oil spill task, over whom the teacher kept tight control, and students who opted for their own standards and inquiries, who were given more freedom. Taking control over one's learning appeared to translate into more control over one's actions and how the task could be accomplished. The group of students on individual tracks were able to move to work in different places and seek help as needed from different experts, whereas students doing the oil spill standard remained in class. Tight teacher control of the oil spill task and of task design was followed through with tight teacher control of group conduct.

The teacher typically checked in with all groups and individuals several times a session and as in cycles one and two, kept track of student progress using Google Docs. As the teacher circulated the room there were multiple micro-teaching conversations with individual students on different topics, depending on what students were working on. As an example, during week ten, in the space of 15 minutes the teacher first helped Haeata (doing option one open inquiry) with his investigation write up, then talked with a group of oil spill students about controlling variables in their practical work (option four), before giving student B advice on where to go next with her research standard (option two). At other times during that week the teacher also acted as an advisor, for example, by telling Jeff to see the physics teacher for help with formulating questions for his investigation (option one). She was also a resource coordinator, for example, working with the technician to ensure equipment for practical work was available for the oil spill standard.

### *8.3.2 Option four: Guided inquiry*

Of the options the teacher set out, the oil spill standard was the 'safe' choice. Those who opted to do the oil spill practical received structured support within the limits of what is permissible at level two NCEA. For a practical investigation at level two the teacher may give guidance to students as they independently plan, carry out, and report on a teacher-chosen investigation. The oil spill group stayed and worked in the laboratory, seated together in the back half of the room, under the teacher's constant supervision and able to access her support.

At the beginning of the term, the teacher supplied the group with a booklet intended to equip students with necessary conceptual knowledge. It contained information about scientific method, dependent/independent variables, and reading and revision exercises. There was also a practice practical assessment which involved making parachutes from different materials that would support a small mass. Similar to cycles one and two, this practice exercise was the trial or formative task before the actual assessed work began. A plastic bin containing materials for making parachutes was ready for students to use once they had planned their investigation and the teacher had checked their method. The teacher argued that while this preparation work was necessary, students would only *"care"* about their learning once they embarked on the *"real"* oil spill assessment. She differentiated the oil spill group from those doing *"individual projects"*.

> *Teacher to researcher: All these ones that are doing their individual project are fairly motivated, but with the practical group…the care factor won't really come in until we do the real one.*

The *"real"* (assessed) practical involved finding, testing, and discussing the most effective method for cleaning up oil spills using the absorption method. Students first read about, researched, and discussed a variety of methods for cleaning up oil spills. The teacher worked with small groups, giving guidance about what information to focus on and extending students' learning outside of the standard. Although the assessed task was about absorbency, they also found out about other methods of cleaning up oil spills. To do this, students accessed a variety of teacher-provided and self-sourced digital resources.

> *Teacher to small group: Can you put in a little bit about how dispersants work? (She talks through on-screen information and diagrams with the group).*

Students often worked together to discuss ideas. Student S and Tangaroa found a website resource written specifically for New Zealand science teachers and students (University of Waikato, 2018). The information on the website prompted

Tangaroa to wonder if it was possible to remove oil by experimenting with burning it off. He was keen to try this but was not permitted.

> *Tangaroa to student S: What about burning it off? If it was on water...like, if you put oil into a bath and …*
>
> *Student S to Tangaroa: When oil spills from a ship or whatever, if it's still on top of the water, they burn it. That was in the research (pointing to the website on the laptop screen).*

The conversation that followed was about whether this *"burning it off"* solution might cause other environmental issues.

In weeks five through to seven of term three, the students were provided with materials such as Pink Batts, sponges, and dish-cloths to test for oil absorbency. They were also able to bring in their own materials for testing. However, before being given permission to proceed with the practical trial, students needed to satisfy the teacher that they were ready to do this. The teacher strictly monitored and controlled student progress. She set limits, including group size. In contrast, students doing their *"own thing"* were given permission to carry on as they wished.

> *Teacher to whole class: You people doing the research standards and your own thing, you're well underway, and I'm happy for you guys to get on with what you're doing. If you want to go grab a laptop, do that.*
>
> *Those of you working on the practical, you did a trial the other day, but I'm not at a point where I'm willing to let any of you start the real assessment. I don't think that any of you provided me with a plan, nothing was presented to me that made me feel confident that you would actually be able to go ahead and gather information at a year 12 level for this assessment. Today I will not let anyone start the practical work until you can show me a workable method and you've thought about how you're controlling variables. Also, only about seven of you have shared your (Google Docs) logbook with me. Remember each block you*

*work on for the practical must be dated with what you worked on. I'm only going to let you (work in) pairs, because the group over here with four boys, that's too many and it meant (last session) that only one or two of you were working.*

Once they were underway, students in the oil spill group completed their practical work with few issues. Fair testing involved repeat trials of immersing different materials into oil, removing the material and draining, before measuring the amount of oil absorbed.

Next for their individual, independently assessed write-up, students needed to complete results tables and suitable graphs, identify variables and account for variability, interpret data and make conclusions, and write discussions which linked to appropriate science ideas. The teacher was able to guide students to suitable resources and provide background information to achieve this. For example, student S was writing his discussion of science ideas for his oil spill practical. I observed him watching a TeD cartoon representation explaining the chemistry of why oil and water don't mix.

*Researcher to student S: Why are you watching this?*

*Student S: Because (the teacher) recommended I watch a video about it.*

*Researcher: Because…?*

*Student S: Because…I don't really understand it…how it works…*

*Researcher: And you're trying to write it up for the practical. Is the video helping?*

*Student S: Yeah…*

*Researcher: After watching are you going to be able to write an explanation?*

*Student S: Probably. I'll probably get up a website as well.*

Week eight was exam week, and weeks nine and ten were taken up with finishing tasks for hand-in.

**Interpretive discussion**

Of 17 students in the oil spill group, 13 gained an Achieved grade or higher (six Achieved, six Merit, and one Excellence). Two students left at the end of term three to study at Polytechnic and did not complete the standard. Two students failed to hand any work in for assessment resulting in DNC (Did Not Complete).

Mallya et al. (2012) argue that an inquiry context which has been carefully selected by the teacher can challenge and extend students' learning. In this option students were given opportunity to extend their knowledge-in-practice of the fair-testing scientific method and to develop scientific literacy associated with an important environmental issue (best methods for cleaning up oil spills) as they read, questioned, and discussed. The type of investigation that the students completed was consistent with Blanchard et al.'s (2010) definition of guided inquiry (see section 4.2), where students independently plan, carry out, and report on a teacher-chosen question. The context and inquiry question were both supplied by the teacher; that is, the *'what'* of the learning was prescribed. Walkington and Bernacki (2018) found that context personalisation at the grain size of a larger group resulted in individual students responding with less interest in the topic. However, in this case, students had a variety of reasons for selecting this option that were unrelated to the topic itself, for example, gaining credits or the desire to do practical work (section 8.2.4).

It is of note that the guided inquiry students also had their *how, where,* and *with whom* chosen for them by the teacher. Students who chose this option stayed in the laboratory with the teacher, who positioned herself in a taskmaster role. For example, before starting the practical trial for the oil spill assessment, each student had to present the teacher with a *"workable method".* The teacher also directed who students could work with, permitting only pairs rather than larger groups, to ensure everyone was on task and contributing to the group. The difference between the teacher's treatment of the guided inquiry students and those who opted for the more self-directed options is reminiscent of Deed, Lesko, and Lovejoy's (2014) depiction of teachers attempting to balance the loosening or tightening of their "pedagogical grip" (p. 382) between teacher-directed and personalised approaches. Tight teacher guidance meant that students' learning was not personalised in the same sense as cycles one and two, where they were offered openness within a closed system (Cowie & Penney, 2015). In fact, the students who did not take up identities as self-directed choice-makers were then afforded less choice and were instead positioned by the teacher as needing to be managed. This could be considered a step backwards when taking into account original action research goals of enabling diverse learners to take more personalised and self-directed pathways through science (Ministry of Education, 2013). However, the teacher's actions in scaffolding tasks and supporting this group reflect an unwavering sense of duty to help students achieve. She considered that failure to provide this option as an alternative to the other more self-directed options would have carried a risk in terms of whether students could gain credits or not.

### *8.3.3 Option two: Self-selected structured inquiry*

Taabah, Sophie, and Anshu were among those who chose to complete self-selected internal options. Data from these three students is presented here to illustrate their personalised pathways.

*Weeks 1-4, term 3*

Taabah worked on the earth science extreme environment standard. Earlier in the year, the context of penguins in Antarctica was used for the practise assessment in cycle two (see section 7.2.1). Taabah had not completed this practice assessment as she had arrived at the school in term two, so decided to take advantage of the resources and information already on offer. She had decided this option would be easier and offer more credits than her original choice of the HPV vaccine within a biology internal. She wanted a high mark in this achievement standard, but as she had other assessments looming, also wanted to complete the work *"as quick as I can."*

> *Taabah to researcher: I talked to a few people, they said just do the penguin, apparently it's easier and there is more information about it... and I don't mind because I have other internals, I need to find something that's easier, that I can do, but also, I can get a high mark on. Because I have this, I have a Classics internal, an English internal, and I have a computers internal, so I need to find something just to… (focus on, get done) as quick as I can.*

Sophie was one of the most ambitious in terms of completing standards. Sophie lived near the school and had permission to come and go, often choosing to work at home. Her aims for the term were to complete a biology practical and study for the earth science external. Early in the term she used class time to focus first on completing the practical work associated with the biology internal. Rather than choose her own context for this, she opted to follow the biology class who had completed the standard earlier in the year with a practical investigation into the respiration of yeast at different temperatures. In week two, Sophie was well underway with her biology internal, having already completed the practical work. However, she had not yet completed the conceptual learning needed to support her discussion of results.

> *Sophie to researcher: You know how I did that internal (biology investigation)? I'm up to the bit where I have to do my discussion. (The biology teacher) said 'Oh wait you can't do the discussion because you haven't got any learning about what you need to discuss'. So I'm doing the learning now…*

Other students supported Sophie by telling her what she needed to know. Sophie told me about a conversation with students in the biology class: *"…and they said, 'Oh, do you know about catalysts and enzymes?', and I said, 'No'…".* The biology class learnt this information together, with the teacher teaching them at the whiteboard, prior to completing the practical. Sophie instead was *"a bit all over the place".* She had a biology workbook and was making her way through the relevant sections with the biology teacher's help, reading and answering questions.

> *Sophie to researcher: I didn't get the back-learning to do with respiration so I was a bit all over the place but the (biology) teacher will help me get through it.*
>
> *Researcher: Does the (biology) teacher have time to talk you through it?*
>
> *Sophie: Yes but I will read the stuff in this book first.*

In week four, and having completed her *"back-learning",* Sophie negotiated a date with the biology teacher to *"make herself"* complete the discussion for the biology practical assessment.

> *Sophie to researcher: I just need to finish one more page of learning and then I'm going to revise it all and then I'll make myself do it, and that's Thursday.*
>
> *Researcher: You said 'make' yourself do it.*
>
> *Sophie: Yeah, I've got to get it out of the way.*
>
> *Researcher: How do you feel about it?*
>
> *Sophie: Stressed.*
>
> *Researcher: Because…?*
>
> *Sophie: I've got a lot of stuff going on, a lot of work to catch up with.*
>
> *Researcher: How do you feel about the actual assessment, the knowledge – do you have enough?*
>
> *Sophie: Oh yeah, that's fine.*

At the beginning of week two, Anshu had decided on the biological validity standard but was still unsure about a context, and still googling possibilities. By the end of week two Anshu decided on a topic (Hepatitis B vaccines). With the biology teacher's guidance, she was gathering different sources to analyse including online video clips along with pamphlets from medical clinics and other printed media. After this initial preparation she was able to work independently on her research. Anshu explained to me: *"I'm analysing the sources at the moment and writing it in my own words."*

*Weeks 5-10, term 3*

Taabah worked independently on her research and checked in with the teacher regularly. Taabah had also began to study for the mock external examination. She tended to remain in class, switching between her two different tasks and approaching the teacher for help when needed.

Once the assessment was complete Sophie switched to studying for the external examination, working through an earth science workbook, liaising with her usual teacher once again when she had questions. She was not seen in class very often as she tended to work at home or in other areas of the school.

Anshu spent her time working in the biology area where she was able to sit with a friend from that class and access the biology teacher for help with the task. The biology teacher also had knowledge about the best places or websites to find resources.

During week eight, normal classes were not scheduled as mock examinations were held instead. Students returned to school for weeks nine and ten and continued to either finish their internal work or revise for the external. During these weeks, students seemed able to progress with their research and writing with intermittent support from the teacher. They were often not in class, working upstairs or in the biology area. Students accessed outside support (the biology teacher) for help with finding information and making sense of what was required in the achievement criteria. Again, the biology teacher was asked to mark the biology-based standards using her expertise and knowledge of the standards.

*Week 1, term 4:*

In week one of term four I asked Sophie and Taabah for their thoughts on the type of learning offered in their science programme. Taabah liked that people could work in their strengths and Sophie appreciated the freedom to *"tell the teacher"* what she wanted to learn.

> *Researcher to Taabah: What was it like for you this year, having all this choice?*
>
> *Taabah: Cool, cos I like all three sciences.*
>
> *Researcher: Would you rather have been told, 'You're all doing this?'*
>
> *Taabah: No cos everyone has their strengths. Cos some people aren't good at practical but they're actually good at write-ups.*

*Researcher to Sophie: How has it been, then, this year, having all this choice?*

*Sophie: Amazing. I've always wanted to do earth and space, and I just tell (the teacher), 'I want to do this, and this…'*

**Interpretive discussion**

Of the five students who chose to work on self-selected structured inquiries in different science disciplines, two received Excellence grades, one received Merit, and two received Achieved.

In this option students could complete a research or practical investigation from any of the available internal level two achievement standards, using the different science disciplines as a basis for making a choice within an area of personal interest. Context choice was open to the individual, however the assessment criteria within the separate achievement standards served to pre-structure the tasks and questions for inquiry. As such, this option was termed a self-selected structured inquiry (Walkington & Bernacki, 2018).

For these students, learning was personalised in the sense that they chose *what* to learn as well as *why* to learn, with this sometimes involving the balancing of conflicting agendas. For example, Taabah privileged expediency and achievement over her original interest in her first chosen topic. Students chose *where* to learn: Sophie worked at home and in class, and Anshu sat in the biology class as she worked. Students could also choose *with whom* to learn. They were supported and coached by their class teacher and the biology teacher as expert-enablers in a manner comparable to that of the structured inquiries in action cycles one and two, and in much the same way as described by Ketelaar et al. (2013). Initially the teachers helped students to decide on or find a topic and then dispensed help as and when it was needed. Students moved freely across flexible spaces to access the biology teacher's specialist knowledge of resources and achievement standards. Deed et al. (2010) claimed that in personalised environments, student agency was influenced by a shared understanding (between teachers and learners) of the affordances of open spaces. Without the ability for students to exercise agency in deciding with whom it would be most helpful to learn, it would have been less possible to offer choices across the full range of contexts and investigations available within the level two achievement standards.

There was some evidence that taking up an identity of choice-maker in this option was linked to students experiencing themselves as self-managed, independent learners. Taabah juggled science assessment with assessments in other subjects and drove herself to finish *"as quick as I can".* She achieved the high mark she was aiming for, gaining four credits at Excellence. Anshu worked independently but accessed specialist help as and when she needed it from the biology teacher. She gained a Merit. Sophie independently studied a biology workbook before asking for help from the biology teacher and *"making herself"* complete the discussion. She gained an Achieved grade. In Sophie's case it was possible to notice the influence of the achievement standard working to lead the learning and structure her inquiry (Hipkins & Vaughan, 2005; Locke, 2005). She conducted the practical first before completing the required *"back learning"*, relying on the teacher to help her *"get through".*

Overall, this small group of students seemed to appreciate the flexibility that enabled them to choose both their course of study and how they achieved the desired outcome, and all were successful in gaining NCEA credits for their work.

### *8.3.4 Option three: The external examination*

*Weeks 1-7, term 3*

Data depicting some of the actions and decisions within the group who studied for the external earth science examination is presented in the next two sections. A group of six students (student L, student J3, Taabah, Sophie, Jeff, and Anahera) chose to attempt the external mock examination in week eight. The earth science external was an obvious choice as students were able to leverage earlier learning in the internal geological processes standard. Students studied for the mock exam by themselves or in groups using a workbook supplied by the teacher, and were supported by visits from the teacher to answer questions and explain aspects of conceptual knowledge.

Sophie began looking at requirements for external study early in term three, while she was working on her internal. She wanted extra credits and appreciated the flexibility offered by the teacher:

> *Sophie: I'm just looking at the exam and looking at what I need to study for. I want to get as much credits as I can from this*

*course because I am running low at the moment. In other courses like English they have a set plan, you can't get out of it, (there are) set internals and you have to do what the teacher says, it's not flexible. But in this course (the teacher) just throws them at you, what you need and what you want to do.*

*Researcher: How are you going to do the learning for this, because the teacher won't teach it formally to the whole class?*

*Sophie: We have lots of resources, she will help me in class. I can also ask (Geography teacher).*

Sophie planned to work her way through the earth science workbook. She planned to look at websites, demonstrations, videos, and TeD talks. She took a proactive approach to ensuring she had access to the teacher's expertise:

*Sophie to teacher: Should we just sit down and sort out a plan for what we need to cover…?*

Taabah was also considering doing the external. She told me: *"My dad always wants me to get tested on earth and space because he was actually going to be a scientist, so he is pushing me into it."* After completing her earth science internal standard, Taabah began to work her way through the earth science workbook. She was not really worried about credits, as she told me she *"will have enough"* without sitting the external examination. This influenced her decision to take a *"see how I go"* approach.

*Taabah: If I fail the mock (exam) then I'm not going to do (the external examination), I just want to see how I go.*

As term three progressed, students were more focussed on mock examination preparation. Sophie, Anahera, and Taabah often sat to work together using the earth science workbook which focussed specifically on content prescribed for the standard and on examination-type questions. I was curious to find out what students thought about working in such an independent manner when learning detailed conceptual knowledge. Anahera liked the independent styles, whereas Taabah said it would have been easier if the teacher had coached them through the new concepts and definitions, similar to the way she was taught at her *"old school"*:

> *Researcher to group: What's it like learning out of a book, like that? (indicating towards the workbook)*
>
> *Anahera: I like it.*
>
> *Researcher: What do you like about it?*
>
> *Anahera: I don't know, I just like how…the info's there…*
>
> *Researcher: How would it be different, say, if the whole class was doing this (standard) and the teacher was up there (indicating to the whiteboard) teaching it, how would that be different? What would that be like?*
>
> *Taabah: That's what used to happen at my old school. I found it much easier because the teacher goes through it more…like, they write the definition or whatever on the board and like, we have to read it, and then they rub words off each time….*

In week eight, normal classes were suspended for examination week during which five students sat the mock earth science external. Anahera missed the mock examination but planned to complete it in her own time.

In week ten, students received their mock exam results back. None of the five students achieved, although Jeff, Taabah, and Sophie were *"very close"*, according to the teacher. The teacher talked through the paper with the group and promised to give more targeted support in term four leading up to the external examination.

> *Teacher to students: I'll get some revision things together for the next few weeks (first few weeks of term four).*

I talked to Jeff about his Not Achieved in the mock exam:

> *Researcher: You were quite close to passing?*
>
> *Jeff: Yeah, yeah, I was.*
>
> *Researcher: And how do you feel about going for the external now?*

> *Jeff: Oh, really good. I feel like it's coming along. I had a look at an exemplar. A lot of the things I did (in the mock) were just not in enough detail so I need to get that actual detail.*

**Interpretive discussion**

Five students attempted the external examination achievement standard at the end of the school year. None gained an Achieved grade. The teacher indicated she blamed herself for this, remarking to me that the students had perhaps needed more targeted support than they had been given. However, there are other factors that may have influenced this outcome, and I discuss some of these below.

In this option students could choose to study for the earth science external examination in addition to completing one of the other options. There was no inquiry component or choice of context associated with this option. Students needed to demonstrate understanding of specific earth science concepts in selected contexts using appropriate earth science vocabulary. As seen in phase one, the teacher-as-expert in transmission mode, who structures and delivers information and helps students to learn by using reinforcing activities, is often considered to be the most effective way of preparing students to do this (Spiller & Hipkins, 2013). Although the students worked independently through an earth science workbook and were supported by micro-teaching episodes, the fact that no students achieved could be seen to reinforce the need for more consistent input from the teacher-as-expert to ensure solid learning and revision. It could also be seen to reinforce phase one findings where tensions between knowledge-based external assessments and more personalised, self-directed learning approaches were noted (sections 6.1.3, 6.2.3, and 6.3.3).

Other factors could also be considered to be influential in these results. The students who entered the external earth science examination did not have a history of success in science external examinations (see section 7.1.3). Of the five students, three had not achieved any level one external science standards. The other two students had achieved one external science standard at level one (one student gained an Achieved grade in biology, one gained an Achieved in physics).

Time to focus on learning for the examination was a limiting factor. This was largely squeezed into the last few weeks before the mock examinations and once students had completed their chosen internal standard.

Another factor that may have been influential in students' effort and preparation for the examination was their plans for the following year and the overall number of level two credits that students had already accumulated before the examination. Sophie knew she had been accepted into Vet Nursing at Polytech, while Jeff knew he was beginning a building apprenticeship. Both were already well on the way to safely accumulating the requisite 60 credits required at NCEA level two. Taabah also had *"enough"* credits going into the external examination.

Lastly, online digital tutorials can be used to support individuals to learn new knowledge at a pace that suits them. Typically, most custom-designed educational software includes a 'repetition until mastery' feature (Education Perfect, 2017; Learn Coach, 2018). Ruano-Borbalan (2006) argues that in personalised environments, technology needs to take on much of work of supporting students with new learning and revision. In this case, students did not have access to digital support of this type because a customised tutorial-type programme for the level two earth science external examination was not available at the time. Digital support was available for other NCEA external science achievement standards at levels one and two in chemistry, biology, and physics (Education Perfect, 2017).

#### *8.3.5 Option one: Open inquiry*

A small group of students opted to take their own track by formulating and investigating their own science questions. The data below show what happened as these students progressed through the term. As far as possible I tracked all students in this group, however, there were times when I did not see them due to their (or my own) absences or if they were working in another part of the school.

**Group work: Joseph, Haeata, student J and "The science of attraction"**

*Weeks 1- 6, term 2*

The teacher was supportive of Joseph and his group but wondered how she could make their science of attraction investigation *"fit"* into the level two achievement standard matrix so that it could be assessed for credits. Joseph, the teacher, and I were talking about this together:

> *Teacher: It could fit in with the (biology) validity one. There would be news articles on gender and sexuality, but I don't know...you've got to analyse the science in it. Talk to Mrs*

*(biology teacher) and see if she can make it fit that one. See, that's more of a research-based one, looking at news articles or information given to the public like pamphlets, speeches, internet…*

But Joseph was not happy with the idea that his project would *"fit"* into a research standard. He wanted a more practical, active, focus.

*Joseph: But can I go around to people and like, ask them, like, what do they find attractive? I had this idea - (teacher interrupts).*

*Teacher: - I like the idea, I just want to make sure it fits something…I just want to make sure we can get something out of it.*

During this conversation, I was trying to find out more about Joseph's idea.

*Researcher to Joseph: …you had this idea…*

*Joseph: I had this idea to get a few guys in the class and get them to speak into a recording, like, ask them questions, what they like, what they their hobbies are, and see what a girl finds attractive about that guy…*

I was interested to note that Joseph saw collecting voice data as a legitimate option considering his work in oral assessment earlier this year. The first hurdle was to find a standard within which the question fitted. I wondered if the investigation might fit into the biology practical standard:

AS91153 **Biology 2.1:** Carry out a practical investigation in a biology context, with supervision

4 credits Internal

(NZQA, n.d.-e).

*Researcher to teacher: Is it an investigation in a biology context?*

Explanatory notes in this standard specify that students must collect data relevant to the purposes of the investigation.

*Teacher: It has to involve collecting data.*

*Researcher: He'd be collecting data, but it would be social data.*

*Researcher to Joseph: Go and do some thinking, put a question or two together about what you want to investigate. If you wrote a couple of points down, then we could work more with it.*

*Teacher to Joseph: Let me investigate (which standard the project could fit into).*

During the first week of term three, Joseph, Haeata, and student J firmed up their ideas. They wanted to gather research on what people considered attractive in other people and relate this to the way cartoon characters are designed. They planned to survey 50 students using cartoon images taken from the internet.

*Joseph "(I want to) Grab photos from the internet and get pictures of biceps and stuff and use cartoon characters and Disney characters and see what people find attractive about them because a lot of people say that some of the Disney characters are very attractive."*

The teacher meanwhile had been talking with the biology teacher and investigating options and allowances within the assessment criteria. It was decided that the project could be assessed within the biology investigation standard.

*Teacher to researcher: Apparently you don't have to do a quantitative gathering of information, you can do something qualitative and survey based.*

As per regulations for the internal investigation standards, the boys were permitted to collect data by working together in their group before completing their write-ups individually. To be assessed within the investigation standard the group needed to ensure their survey mirrored the structure of the scientific method:

*Teacher to Joseph, Haeata, and student J: The big thing Mr (biology teacher) says for your one (project) is setting your* *survey up like a science investigation. Cos the criteria for the standard want it set up like a practical, even though it's a survey, so you'll have to talk about…obviously your aim and prediction will be easy, the variables, you're going to have to change and measure, and then things you're going to try and keep the same, so it has to be set up in that format.*

A teacher with an interest in project-based learning had also been mentoring the group and recommended they take on different roles, with Joseph as leader.

*Joseph to researcher: In Pathways time Mr (Pathways teacher) talked to our group about setting roles so I'm getting (student J) on the survey side of things, helping get the survey together and I'm getting him to get pictures of traits and things. I've got told I should be leader, apparently, we're all getting information, after that I'm going to go through it all.*

The group continued with their plans during weeks two and three, under the guidance of the teacher and the Pathways teacher, who wanted the boys to present their project when it was finished. They were independent and self-driven.

*Researcher to Joseph at beginning of a session in week two: So, what's your plan for this session?*

*Joseph: Probably get a little bit more information, I might read through it all, see what we have, and maybe go through some of the websites the boys have gone to cos I told them to write the references down.*

After this conversation the boys moved next door to the biology class and sat on the floor together to begin their work.

In week four, I found Joseph working in the upstairs learning commons with student J. Student J came to level two science with just nine internal science credits at level one, and no external science credits. Although he had achieved the standards he had attempted this year, he had been inconsistent in his application to his work. In cycles one and two he had been noticed by me watching YouTube or off task during science sessions many times.

*Researcher reflecting later into the voice recorder: Is this the first time all year I have seen student J working consistently towards something?! He is part of a team, and he wants to do it – such a difference to earlier in the year when he always seemed to be on YouTube.*

Google Drive was open on both boys' computers. The boys had narrowed the focus to females looking at males as the project was getting too big. Joseph as leader had his group working on different tasks.

*Joseph to researcher: I'm going through all the research that we've got and I'm reading it and highlighting it all, the important stuff that's relevant and I'm going through all the links and looking at all the articles while (student J) and Haeata go through and get photos for our survey and design stuff for our survey.*

Joseph was experiencing the inquiry as a process of 'not knowing' but of finding out. He was careful to look up words he did not know:

*Joseph to researcher: Once we've done the survey I'll get (student J) or Haeata to put the data into graphs and then once we've finished collecting all the information and looking at words I don't know and stuff, we'll put it into a report and then I'll show Mr (Pathways teacher) and (the science teacher).*

Joseph had not formed a hypothesis for what his eventual results might tell him.

*Researcher to Joseph and student J: What's your hypothesis at the moment?*

*Joseph: No idea.*

*Student J: At the moment for the eyes, I reckon people'll go for the brighter coloured eyes rather than the darker coloured eyes because the brighter coloured eyes stand out more.*

In week five I was interested in whether the boys would manage to relate what they were doing to science ideas that would enable their work to be assessed against the level two biology investigation standard.

> *Researcher: What science are you going to relate this to? Because you will need to relate this to biological or scientific ideas to do it within the standard.*
>
> *Joseph: There's one on here – Dr HF, she's a anthropologist, I think (he shows me the article titled 'What is love? Science has the answer').*
>
> *Researcher: How will you know whether it's good information? Or scientific information?*
>
> *Joseph: We'll check up on the author before we read to make sure we're not wasting time. We've found a lot of the same answers (in different sources) and watched a few videos.*

The teacher kept tabs on the project and kept in conversation with the biology teacher to ensure the group would end up *"getting credits"* for their work.

> *Teacher talking to Joseph, Haeata, and student J in week six: According to (biology teacher) one of the criteria (of the standard) is to be able to graph your results…the current way you've got collecting (the data) is you've got your four pictures, and then...I think, to get better data, ask people to rank them from one to four, maybe one being most attractive then four least, and then why, give a reason for your ranking, and then we add total scores...I just feel like we need to get a bit more data.*

*Weeks 7-10, term 3*

For the whole of week eight, normal classes were suspended for exam week. During weeks seven and nine and when they were present in class, the boys collected data from 50 students and began collating their data into tables and graphs.

By week nine the boys had finished their data collection and group-work ended as they began their individual write-ups for assessment. Joseph knew how he was going to go about his write-up:

> *Joseph to researcher: I'm gonna get it (the data) and look at the results, and see what the pattern is, if there is a pattern, and then I'll, like, write it into a report; introduction, hypothesis, aim, variables, controlled variables…um…results and data and stuff, and then I'll write a conclusion that links back to the results and data and then…I'll connect that with the science ideas, to all the other research I have been doing….*

Haeata was not so confident. He needed help to find science ideas that could be linked to the data they had. The teacher suggested he look at ideas of natural selection. Haeata searched for information online, and although he was able to write a definition for natural selection, to link scientific ideas to the project he needed a more nuanced search. Using a search term "sexual selection in humans" yielded dense, scientific terms which were inaccessible to him. A common tactic when searching for scientific information at an accessible level is to add "for kids" after the search term. Because of the topic, this strategy was not going to work in this case. Further searching, this time using the term "mate choice in humans" produced some helpful information at a level Haeata could understand.

*Week 1, term 4:*

Haeata finished his write-up and handed it in in the first week of term four. The work was given to the biology teacher to mark and Haeata received a Merit.

The work needed to be finished by week two of term four. In week one student J had not yet completed his write-up, and the teacher was unsure if he would. No longer part of a team, but alone with his individual write-up, he seemed to be struggling. He was also absent from class more often than he was present, which made it hard to connect with him and help him to progress. When I saw student J at school that week, I asked him how he was progressing. At that stage I wondered if he would have been better served in terms of credits by doing the structured oil spill option.

> *Student J to researcher: I just need to get it in.*

*Researcher: Does it make you wish you did the oil spill option?*

*Student J: No, I'm glad I did this one.*

Joseph also was slow in the process of finishing off, but the teacher felt he was on track to finish.

> *Teacher to researcher: He knows what he (Joseph) needs to do…and he reckons he's working on it… I talked to him and said he needed to concentrate on what the variables were and how he controlled them. I'm hopeful we can get them (Joseph and student J) over the line. It's looking a lot better than I anticipated.*

I went to find Joseph, who was sitting on the floor in the biology room.

*Researcher to Joseph: What are you up to today?*

*Joseph: I'm finishing off my conclusion, fixing any errors and completing my method.*

*Researcher: What's the plan for hand-in?*

*Joseph: Ah…next week sometime?*

*Researcher: What was it like having choice, you could have done the oil spill practical, or other options? What was it like doing this (your own project)?*

*Joseph: I like this one because I got to choose it myself and if I get to choose something that I want to do it makes me want to do it more because I've actually chosen it instead of having it given to me.*

Joseph finished his work and handed it in at the end of week two. The work was given to the biology teacher to mark, with Joseph receiving an Achieved grade. Students left school in week three of term four and student J had not handed any work in for marking, therefore received no credits. I was unable to talk with him as he was not in class in the last week before seniors left.

**Tangaroa: An individual question**

Tangaroa's question about how and why in times past, Māori seemed to be able to reproduce or mate with close blood relatives and suffer no genetic deformities in the offspring needed also to fit into a standard. The teacher again needed to do some investigation. None of the standards at level two seemed to *"fit".* At the beginning of term three she reported back to Tangaroa.

> *Teacher talking to Tangaroa: I talked with (biology teacher). We were trying to find a standard and he actually reckons it fits with a level three standard that he reckons you'll be capable of doing, so, it could work, that idea, and he's actually available in this block. And (biology teacher) was kind of excited about it and thinks at level three it is doable.*

The level three standard was:

> AS91602 **Biology 3.2:** Integrate biological knowledge to develop an informed response to a socio-scientific issue
> 3 credits Internal
> (NZQA, n.d.-e).

In week two I notice that Tangaroa was working on the oil spill practical, however, my assumptions at this early stage that he had abandoned his project were incorrect.

> *Researcher: Tangaroa, you had that amazing question that you could have chosen (to work on) but you've moved to do the practical instead?*
>
> *Tangaroa: I'm doing both.*
>
> *Researcher: How're you going to work that?*
>
> *Tangaroa: I'm going to do this practical one first, but I've already done some research (on the other question).*
>
> *Researcher: Have you found anything?*
>
> *Tangaroa: I found that if Māori back in the day had deformed kids then it would be like…bad…*

*Researcher: A bad sign? But I remember you said there weren't so many deformities even though they did closely inter-breed?*

*Tangaroa: But they didn't talk about them much.*

*Researcher: So, you are thinking they were perhaps there, but they weren't talked about?*

*Tangaroa: …and they would get killed.*

*Researcher: So, you think the frequency of genetic deformities might have been the same…or…?*

*Tangaroa: I don't know yet.*

Tangaroa had decided he would complete the practical first and then work on the project in the second half of the term once he had time to read around the topic.

*Tangaroa: Cos everyone's already on this (the practical).*

However, the oil spill practical took longer than he anticipated.

*Week 5, term 3:*

*Researcher to Tangaroa: So, what's your plan for today?*

Tangaroa and student E were shared into the same documents and were working together. Tangaroa was updating his logbook and planning the experiment.

*Tangaroa: I want to get this done as fast as possible, so I can get into the practical.*

The term went by and Tangaroa completed (and achieved) the oil spill standard but did not progress very far with his original inquiry question, although he was still keen to pursue it. The teacher began talking about offering science as a level three course, and they decided together that he could investigate his question, at level three, where it *"fits",* the following year.

**Jeff: An individual question**

*Weeks 1- 5, term 3*

Jeff's idea for an inquiry into the physics of gun recoil seemed to fit easily into a standard:

> *AS91169* ***Physics 2.2:*** Demonstrate understanding of physics relevant to a selected context
>
> 3 credits Internal
>
> (NZQA, n.d.-e).

Jeff usually worked in a different area of the school where he was closer to a physics specialist who was available to work with him and who *"knew more"* than the science teacher, whose specialist subject was chemistry.

> *Jeff to researcher: (The physics teacher) knows more about physics and she's been helping me with what I should do and what I should do next.*

He was an independent worker, able to take direction and to continue with research and reasoning on his own. I talked to him in week two when he was trying to work out the force that a bullet has when is ignited.

> *Jeff to researcher: If I know the force, from that I can state that the force will be directly proportionate to the amount of recoil. I know the mass of the bullet, I know the velocity – I searched it up – so now I'm trying to work out the acceleration of it so I can get the force using F=Ma.*

Later in weeks two and three, Jeff was still working to find information.

> *Researcher to Jeff in week two: How are you going?*
>
> *Jeff: I'm searching up the history of how the physics came to be like, in this case it's how the mechanisms in a firearm came to be.*
>
> *Researcher to Jeff in week three: What are you up to at the moment?*
>
> *Jeff: I'm just trying to find information about projectile motion, so pretty much the speed that the bullet goes and its deceleration.*

In week four, Jeff told me he had refined his ideas about how forces are related to recoil:

*Jeff: Most people would think that the amount of recoil would be proportionate to the force of the explosion but it's not. Because I learnt that force and energy is converted to say, heat and sound. So, the explosion caused heat energy to be formed, and sound, which uses some of the energy, but not all of it, so the rest of it is recoil.*

At this point I was unsure whether he was still investigating his own inquiry question, however, he had a clear end-point in mind:

*Researcher: Where are you heading with the end point of the project?*

*Jeff: I was going to investigate what effect the person's mass has on the recoil. Some people if they've got large arms or big muscles or something when they fire a gun the rest of their body wouldn't move but some people when they fire it their whole arm would move.*

*Week 6-10, term 3:*

In week six, Jeff left his physics inquiry to begin studying for the earth science external and the mock examinations in week eight. After this he continued to spend most of his time in another part of the school with the physics teacher, and I did not see Jeff in class very often. He was able to complete and hand his work to the physics teacher for marking by the end of term three.

*Week 1, term 4:*

Jeff was required to complete extra work and resubmit to gain an Achieved grade in his inquiry, as even with the physics teacher's support, the focus of his inquiry and the work he produced did not meet the specific assessment criteria in the standard. At this late stage of the year, Jeff decided not to do the extra work to resubmit, even though he had the full support of the physics teacher, and even though not much was needed to bring the work up to standard. Jeff's final reflections were that while he received a high level of individual support from the physics teacher, reaching the exacting standard required was difficult. He also told me that *"I learnt something"* and *"I'm glad I did it."*

The teacher admitted to me that Jeff not being finally credentialed for his work *"feels like a bit of a failure".* However, it appeared that Jeff had made a pragmatic decision. According to the teacher, he already had well in excess of the required level two credits and had other more urgent priorities related to his career, such as finishing his Hard Materials assessments before leaving school to begin his building apprenticeship.

**Interpretive discussion**

Of the five students who originally chose to pursue their own inquiry, Haeata gained a Merit, and Joseph an Achieved grade. Tangaroa completed the oil spill inquiry and gained an Achieved. Jeff received a Not Achieved and decided not to resubmit, and Joseph did not submit (DNS).

In this option students could formulate their own science question and pursue a self-directed, open inquiry (Blanchard et al., 2010). All aspects were open to student choice: context, question, methods of investigation, and reporting. Open inquiry and personalised approaches can perhaps advantage the more able students, or those with the social or intellectual capital which provides the wherewithal to think of workable scientific investigations along with ability in terms of independent learner dispositions, language and literacy skills that would enable students to execute and complete the project (Campbell et al., 2007; Leadbeater, 2006). I will now consider this proposition with reference to students who chose the open inquiry route.

None of the students in the open inquiry group appeared to need help to position themselves as question-askers. The teacher, reflecting on this, made the comment that *"this type of learning is not only for the top kids"*. These observations are in line with claims made by others that even those students who are typically less successful academically are capable of asking questions and connecting science to their own experiences (Roth, 1995; Seiler, 2013; Yerrick, 2000). However, the students did require various forms of autonomy support, as suggested by Adler et al. (2018). One form of support was the teacher's acceptance of and willingness to work with students' initial questions, and this was important in maintaining their interest and motivation to pursue a self-designed inquiry. The students needed further support to articulate their wonderings and to formulate investigable questions congruent with criteria in an achievement standard. This aspect of guidance and autonomy support has similarly been noted by Chen and Tytler (2017) who state that teachers need to be actively involved in "monitoring, shaping and responding to students' ideas" (p. 95).

In framing and refining the initial questions and for support during the inquiry process, both teacher and students needed to access other teachers as experts in particular scientific disciplines. Four different teachers offered advice on various aspects of the inquiries. For example, the teacher needed to find standards from the level two science matrix with achievement criteria which were congruent with students' inquiry question so that their learning could be assessed for NCEA. The teacher consulted two biology specialists as she responded to this issue for Tangaroa's question and for Joseph's group inquiry. The flexibility of open spaces enabled teachers and students to seamlessly access this support during class time. Osborne (2013) stressed the affordances of FLS in enabling collaborative, cross-curricula, strengths-based teaching approaches. The ability of students and teachers to move across spaces to access appropriate expertise is also relevant across the different science disciplines when supporting students in open inquiry, especially at senior levels as knowledge within the discipline becomes more specialised and complex (Avraamidou, 2018; Beauchamp & Thomas, 2009; Hart, 2002).

Returning to the argument that open inquiry learning might advantage students who are considered more academically able and looking at Jeff and Haeata's level one science results (see Table 1, section 7.13), it might be assumed that these two students were *"top kids"* and might possess the skills necessary to complete an individual project. Both were able to proceed independently, and by accessing specialist help when needed, were able to complete their inquiries. Haeata was credentialed for his efforts. Jeff was not. Jeff's decision not to resubmit for credits possibly had more to do with prioritising other work and not needing the credits than any lack of skills or ability. Of the other three students, who would not be considered *"top kids"*, Tangaroa formulated a question and made independent progress towards answering it but did not receive NCEA credits for this work. Instead he completed and gained an Achieved grade in the oil spill standard.

Student J especially surprised me with his motivation and engagement during the teamwork part of the investigation. This was because I had noticed many instances during action cycles one and two where Student J exhibited off-task behaviour or seemed unmotivated. For example, he was seen playing games on his digital device (section 7.3.3). The achievement standards permit students to work in collaborative groups while designing an investigation and collecting data, and Student J seemed to be motivated in this group context. However, students are required to interpret and write up their results by themselves. Student J was noticeably less interested and confident in the write-up phase and did not complete the task. Student J's case highlights the need for particular kinds of teacher scaffolding of student autonomy to assist some students to take on and sustain self-managed learner identities and to achieve in high stakes inquiry contexts (Blanchard et al., 2010; Chen & Tytler, 2017; Leadbeater, 2006; Patall et al., 2010). Adler et al. (2018) stress the central role of the teacher as motivator and providing practical support for challenges that students may encounter. In this case, student J may have benefited from more support in time management, and in interpreting results and developing and discussing scientific ideas.

With encouragement from the Pathways teacher, Joseph not only experienced himself as an independent science learner, but as a leader of learning as he led his group through their inquiry. Joseph and his group sustained their interest in the topic during planning and data collection phases and accessed three different teachers' support and expertise at different times in the investigation. Joseph's leadership and the groups' decision making and collaborative work in carrying out their open inquiry are examples of desirable 21st century skills which are valued by the front-end of NZC, but not explicitly assessed within the science standard they attempted (Haque, 2014; Hipkins, 2008). It is the issue of assessment of open inquiries within NCEA standards that I turn to next.

One issue highlighted in this very small trial was the ability of the standards to authentically accommodate students' questions, and the teacher was understandably reluctant to allow students to investigate questions that did not *"fit"* an NCEA assessment standard. Part of the difficult balancing act for the teacher was in helping students structure their ideas for an inquiry within the available NCEA standards while retaining the integrity of their original intent. Different achievement standards were talked about by the teacher and students as: *"a researchy one"*, *"a research-based one"*, a *"report writing one"*, or *"the* *practical option"* (see section 8.2). Within constructionist theory, language is not neutral but produces and constructs our experiences. The language used in each achievement standard and accompanying assessment criteria constructed possibilities for a specific type of learning and inquiry, and thus positioned students as a specific type of learner (Burr, 2003, 2015; Harré & van Langenhøve, 1999).

The issue of fit of students' open inquiry questions with achievement standards was noticeable in the case of Joseph's group. At first the teacher saw the inquiry as fitting a standard she described as *"more of a research-based one"*. The students' open inquiry was at this point was in danger of being closed down, with students positioned as researchers and readers rather than investigators in a more practical and people-focussed sense. Joseph resisted this, asking again if he could *"go around to people and ask them".* The teacher later clarified with the biology teacher that the practical investigation standard permitted the collection of social data and so permitted Joseph's original intention for the inquiry (NZQA, n.d.-e). The teacher still stipulated that *"the criteria for the standard want it set up like a practical"*. On the other hand, in Tangaroa's case, none of the standards on the level two matrix were able to be fitted to Tangaroa's question, which meant he needed to step up to level three if the learning within his inquiry was to be credentialed. These examples illustrate one way that NCEA assessment practices shape students' experiences of science learning and shape possibilities for teachers' practice (Cowie, 2013; Hipkins, 2013; Hume & Coll, 2009; Moeed, 2010).

In summary, findings from this very small sample of five students suggest that it is possible for students' questions to lead learning and achievement in NCEA assessments, but not always straightforward. Students are likely to need high levels of differentiated support to ensure they are able to make and pursue their choices, to enact self-managed learner identities, and to eventually produce work that can be assessed so that they can be credentialed for their efforts. The expertise of a range of specialist teachers from the various disciplines relevant to the different inquiries was required. The affordances and flexibility of the open spaces enabled the teacher and students to access this support.

Section 8.3 has summarised the four options students were offered and made an interpretive comment about implications for teacher and student actions, positions, and identities in each. The final section (8.4) below summarises outcomes for action cycle three and signals future directions for the teacher and the science class.

## 8.4 Wrapping up and looking forward

### *8.4.1 Looking across options offered in cycle three*

Cycle three involved an in-depth action inquiry into a range of options for personalising senior science learning. Different types and levels of inquiry learning were used as vehicles for facilitating personalised pathways. In any science inquiry, research evidence indicates that students should not be left on their own to pursue and discover knowledge. In action cycle three the teacher provided different forms of scaffolding, teacher direction, and autonomy support across three inquiry options. Most students (17 out of 27) chose to undertake the teacher-directed, guided inquiry. Looking across the inquiry options, teacher actions in supporting students in making and successfully pursuing their choices, and thus supporting their identities as choice-makers and self-directed learners who could achieve in NCEA included:

- structuring the learning options to allow students to choose from guided, self-selected, and open inquiries
- informing students of possible contexts for self-selected inquiries while students were deciding on what to do and learn
- accepting then shaping and responding to students' ideas for open inquiries to ensure they were congruent with and achievable within NCEA assessment criteria
- overseeing students and space to permit flexibility in where, how and with whom to learn in self-selected and open inquiries
- directing students and space in guided inquiry
- supporting students in carrying out research or data collection as allowable within NCEA for guided, self-selected, and open inquiries
- record-keeping to track student progress towards achievement in NCEA for the guided, self-selected, and open inquiry students

- scaffolding and supporting students in interpretation and write-up of results, as permitted within NCEA for the guided, self-selected, and open inquiries

Flexibilities and affordances within the four elements of FLS, digital technologies, NZC, and NCEA were exploited to enable and provide the conditions for a range of learning choices in science inquiry. The elements also provided the conditions necessary for and under which students achieved success in high stakes assessment. Different aspects of science learning within the framework curriculum were assessed using the modular NCEA assessment system. Flexible learning spaces enabled fluidity of movement and access to other subject specialist teachers. Digital tools supported student learning in each option by providing access to information and resources. Factors related to NCEA influenced the shaping of the different degrees of openness in inquiry options that the teacher offered in line with meeting her duty to ensure students achieved credits. Factors related to modular NCEA assessment seemed to be a key influence on students' ability to make choices and to take up positions as self-directed learners. These choices included their positioning as needing to achieve in NCEA and their positioning as learners by the assessment criteria within the standards.

### *8.4.2 Summary of overall student choices and achievement outcomes*

The table below displays summary data of student learning choices, standards attempted and achievement outcomes of all students in cycle three (Table 3). Table 4 summarises learning pathways, choices, and achievements of the eight focus students over all three cycles of action research.

***Table 3: Summary of overall student choices and achievement outcomes***

| *Students' choices* | *Achievement standard attempted* | *Initial choices (27 students as at end of term two)* | *Final achievement outcomes* |
|---|---|---|---|
| Option one<br>Open inquiry | Physics 2.2: Demonstrate understanding of physics relevant to a selected context | One student | One NA<br>(Not Achieved) |
| | Biology 2.1: Carry out a practical investigation in a biology context, with supervision | Three students working in one group | One Merit<br>One Achieved<br>One DNC |
| | Biology 3.2: Integrate biological knowledge to develop an informed response to a socio-scientific issue | One student | Changed options into oil spill standard |
| Option two<br>Self-selected structured inquiry | ESS 2.4: Investigate how organisms survive in an extreme environment | One student | One Excellence |
| | Biology 2.2: Analyse the biological validity of information presented to the public | One student | One Achieved |
| | Biology 2.3: Demonstrate understanding of adaptation of plants or animals to their way of life | One student | One Achieved |
| | Biology 2.1: Carry out a practical investigation in a biology context, with supervision | One student | One Merit |
| | ESS 2.2: Examine an earth and space science issue and the validity of the information communicated to the public | One student | One Excellence |

| *Students' choices* | *Achievement standard attempted* | *Initial choices (27 students as at end of term two)* | *Final achievement outcomes* |
|---|---|---|---|
| Option three<br>Earth science external examination | ESS 2.5: Demonstrate understanding of the causes of extreme Earth events in New Zealand | Six students | Five NA in the external examination<br>One SNA (Standard Not Attempted) |
| Option four<br>Guided inquiry | ESS 2.1: Carry out a practical earth and space science investigation | 17 students at beginning of term three, 18 in total. | Seven Achieved<br>Six Merit<br>One Excellence<br>Two students left school<br>Two DNC |

### *8.4.3 Summary of the focus students' learning paths*

The table below summarises the individual context choices and achievement outcomes of the eight focus students over cycle one, two, and three. Table 4 illustrates the very different personalised pathways students took during their year of science study.

***Table 4: Summary of focus students' learning paths***

| *Student* | *Term 1*<br>*Biology microscope internal* | *Term 1*<br>*Choice of context in earth science internal* | *Term 2*<br>*Choice of context in earth science internal* | *Terms 3 & 4*<br>*Own choice of type of standard and type of inquiry* | *Entered the earth science external?* |
|---|---|---|---|---|---|
| Anahera | Microscope<br><br>Merit | Fur seal<br><br>Excellence | Mt Tarawera<br><br>Excellence | Guided inquiry<br>Oil spill<br>Merit | No |
| | *Plans for 2018:* Returning to school, taking level three science, no plans post-school yet. | | | | |

| *Student* | *Term 1*<br>*Biology microscope internal* | *Term 1*<br>*Choice of context in earth science internal* | *Term 2*<br>*Choice of context in earth science internal* | *Terms 3 & 4*<br>*Own choice of type of standard and type of inquiry* | *Entered the earth science external?* |
|---|---|---|---|---|---|
| Anshu | Microscope<br>Merit | Shark<br>Merit | Fiordland<br>Merit | Self-selected standard<br>HPV vaccines<br>Achieved | No |
| | *Plans for 2018:* Returning to school, taking level three science, no plans post-school yet. | | | | |
| Haeata | Microscope<br>Merit | Alaskan wood frog<br>Merit | White Island<br>Achieved | Open inquiry Science of attraction<br>Merit | No |
| | *Plans for 2018:* Returning to school. Taking level three, no plans post-school yet. | | | | |
| Jeff | Joined the class in term one | Humans in space<br>Merit | White Island<br>Merit<br>and<br>Microscope<br>Merit | Open inquiry<br>Physics of gunshot recoil<br>NA | Yes<br>NA |
| | *Plans for 2018:* Leaving school to begin a building apprenticeship. | | | | |
| Joseph | Microscope<br>Achieved | Arctic wolf<br>Achieved | White Island<br>Merit | Open inquiry Science of attraction<br>Achieved | No |
| | *Plans for 2018:* Returning to school. Taking level three, many plans post-school, none definite. | | | | |

| *Student* | *Term 1*<br>*Biology microscope internal* | *Term 1*<br>*Choice of context in earth science internal* | *Term 2*<br>*Choice of context in earth science internal* | *Terms 3 & 4*<br>*Own choice of type of standard and type of inquiry* | *Entered the earth science external?* |
|---|---|---|---|---|---|
| Sophie | Microscope<br><br>Merit | Humans in space<br><br>Excellence | Auckland volcanoes<br><br>Merit | Self-selected standard Biological catalysts<br><br>Merit | Yes<br><br>NA |
| | *Plans for 2018:* Leaving school, Vet Nursing course at Polytechnic. | | | | |
| Taabah | Came to the school later in term two | Came to the school later in term two | White Island<br><br>Merit | Self-selected standard Penguins<br><br>Excellence | Yes<br><br>NA |
| | *Plans for 2018:* Returning to school, taking level three science, plans to go to university. | | | | |
| Tangaroa | Microscope<br><br>Achieved | Polar bear<br><br>Achieved | White Island<br><br>Achieved | Guided inquiry<br>Oil spill<br><br>Achieved | No |
| | *Plans for 2018:* Returning to school, taking level three science, wants to be a teacher or a Youth Pastor. | | | | |

### *8.4.4 Plans for 2018 post action research*

During term three the teacher started talking about running a level three science class in 2018. She first surveyed students informally to ensure she had enough interest before securing approval for level three science to be included as an option in the school's 2018 subject options booklet. At the beginning of term four, 36 students had signed up for the course, with others still to complete their selections. The teacher was hopeful that these numbers would be enough for two general science classes to run simultaneously. This would allow greater flexibility in terms of opening options for students as there could be two teachers team teaching and on board at all times, with different areas of expertise. The level two science course was offered again for 2018 and 31 students signed up. Other science courses at levels two and three also had strong numbers and therefore according to the teacher, offering the level two and three general science options *"didn't affect the numbers in the (discipline-based) classes".* Instead the teacher surmised the students enrolling may have otherwise been *"lost to science".* These numbers suggest that the general science course seems to have achieved the original aim of keeping senior students as diverse learners engaged in science.

In the last week of school before senior students left for NCEA examinations, a group of students were sitting together at a table with the teacher and myself. The teacher was discussing plans for the 2018 science courses. The teacher began wondering about context-based learning by combining standards during term one when the whole class was progressing together: *"Maybe a chemistry internal and an earth science internal and doing 'Acidification of the Ocean'".* She had also been thinking about Tangaroa's question and was going to suggest to him that at level three he combine his genetics inquiry with other cross-curricular learning, *"which could be connected to a place, so a heritage study…".* Thinking about her experiences with Joseph's group inquiry where they collected social data, the teacher told me she was *"keen, after the boys doing a survey instead of a practical, to look at different ways to do that same standard".*

For the new 2018 level two science class the teacher thought she might follow the same format as the three action research cycles; take an earth science focus, begin with a structured start, and gradually open options for choice. However, she wondered about *"maybe opening up the level three class straight away".*

She asked the students sitting with us:

> *Do you think we should start next year like we did this year, with term one everyone doing something similar, then after that we'll offer some choice, or do you think we should branch out straight away?*

I found it interesting that she even asked the question as it indicated to me that she felt confident enough in the outcomes of the open choice approach to launch straight in at the beginning of the year. During the action research it had not been safe to risk 'letting go' until students had achieved a certain number of credits.

This time it was the students who did not want to let go. Haeata had an answer to the teacher's question:

> *Haeata to teacher: We should start off with everyone doing something similar because it's just kind of like training wheels, then branch off.*

Anahera, Sophie, student F, student T, and student S who were sitting with us all agreed, and it was decided that the level three course should follow a pattern similar to the action research cycles with a structured beginning, then choice, but with structure for those who still wanted that support.

In the final discussion and conclusion chapter which follows, I draw together findings from phase one and two to consider the overall question of how the discourse of 21$^{st}$ century learning is shaping possibilities for science teacher and student identities.

# Chapter nine: Discussion and conclusion

Four macro-level elements of science curriculum, digital technologies, flexible spaces, and NCEA assessment were used in this study to frame an examination of ways in which the discourse of 21$^{st}$ century learning might play out in senior secondary science schooling to reposition teachers and students of science in Aotearoa New Zealand.

The overarching research question was:

> *How might the discourse of 21$^{st}$ century learning influence notions of senior secondary science to offer different identity descriptions for science teachers and learners in Aotearoa New Zealand?*

Phase one and two sub-questions were designed to facilitate a situated study of this overarching question in contexts of FLS schools in NCEA science assessment.

In this final chapter, I begin by summarising the ways in which each of the four elements worked at a macro level to create different possibilities for science teacher and learner identities (section 9.1). I then draw these aspects together to foreground the multifaceted nature of science teacher and student identities in response to the overarching research question (section 9.2). In the following section I discuss limitations of this research (section 9.3). In section 9.4, I discuss implications for policy and practice and outline directions for further research. Finally, in section 9.5, I conclude the study by summarising key findings and contributions of this research.

## 9.1 Possibilities for teacher and student identities

### *9.1.1 Possibilities for teacher and student identities within curriculum*

Three aspects of school science as it is addressed in the New Zealand Curriculum (NZC) and interpreted by the teachers in this study supported teachers offering different types of learning choices. Firstly, the non-prescriptive framework nature of the NZC permits teachers and students to design and choose learning pathways that are meaningful to each diverse individual. In phase two action research, the teacher was able to build pathway flexibility in the form of context-personalisation (*what* to learn) and task choice in the form of different levels of inquiry (*how* to learn) into a general science course (Blanchard et al., 2010; Walkington & Bernacki, 2018). This general course was offered by the school as an alternative to a strongly discipline based course (biology, chemistry, physics) (see section 7.1.3). The course appealed to senior students who valued science and wanted to continue to learn in science, but who, in the words of one student, didn't want to be *"just copying things down,* ***no clue"***. Thus, the claim by Hipkins and Spiller (2012) that "curriculum creation at the NZC–NCEA intersection is already able to provide a structural framework within which '21st century' changes are made possible" is supported. Others (e.g. Hart, 2002; Tytler, 2007) have similarly found that expanded meanings of curriculum, such as context-based science learning rather than the teaching of a canonical collection of abstract disciplinary concepts, offers opportunity to make science more accessible and improve the quality of science learning for more students.

Secondly, the value NZC attributes to the development of skills, capabilities, and competencies needed for life and living in a 21st century society provides opportunities and expectations for teachers to offer and scaffold curriculum to support the development of these skills. This in turn supports students as self-managed, self-directed choice-makers. This positioning of teachers and students is illustrated in the portrait of science learning in chapter six, which drew on data from three case study schools from phase one. For example, the portrait depicted students making individual decisions about whether or not they would attend a revision workshop. In the portrait, students undertaking a practical investigation in the context of heat transfer chose to investigate issues of personal import, such as the insulation properties of puffer jackets (section 6.5). In phase two, students were able to decide for themselves the level of teacher support they would receive by deciding to either join the teacher-directed guided inquiry oil spill group or to undertake a more independent, self-selected structured or open inquiry (section 8.2).

Thirdly, inquiry learning approaches are advocated within NZC (Gillon & Stotter, 2011; Ministry of Education, 2007). The overarching Nature of Science (NoS) curriculum strand encourages the development of the epistemic knowledge that is essential for students to experience science as a process of investigation and inquiry (Ministry of Education, 2007a; Tytler, 2007). In phase two, students undertook inquiries involving different degrees of openness and structure, similar to levels of structured, guided, and open inquiry suggested by Blanchard et al. (2010). This range of types of inquiry supported diverse students' identities as science learners and echoes suggestions by Melville and Bartley (2013) that learning as an inquiry process opens opportunities to expand upon the traditional science schooling discourse, which tends to focus on science as a fixed body of conceptual knowledge and hence on students as receivers of this knowledge (Carlone et al., 2010; Tytler, 2007).

That said, findings show that science conceptual knowledge in the 'traditional' sense remains important; therefore, student identities as knowledgeable about science also remain important. One example of this comes from phase two when Tangaroa blended his knowledge of genetics with his knowledge of Māori culture and history to wonder about an issue of inheritance (section 8.2.1). In another example, Sophie learned that Auckland was built on a volcanic field and wondered about what might happen if a volcano was to *"blow"* (section 7.3.4). In other words, it is knowing *about* science that enables one to *not know,* or to be capable of asking productive, science-oriented questions, and to investigate and construct knowledge through inquiry, much as a scientist would. The focus on students' understanding of science conceptual knowledge is also justified from a constructionist standpoint because language is understood to be a precondition for thought (Burr, 2003, p. 7), and it is knowledge of foundational scientific language and concepts that makes it possible to think and know in scientific ways (Burr, 2003; van Langenhøve & Harré, 1999).

Similarly, the identity of teacher-as-expert who is knowledgeable about science remains important. The teacher in phase two needed to draw on her wide and deep science and pedagogical knowledge to support students to frame questions amenable to science inquiry and to guide students through the inquiry process. The findings resonate with work by Williams et al. (2013) who note that teachers scaffolding student inquiries, and especially more open inquiries, require a combination of knowledge of science curriculum, of science conceptual knowledge and of the NoS curriculum strand. Data from this study illustrates that teachers also need to deploy an identity as learner - the teacher in phase two extended her own knowledge as she familiarised herself with a wide variety of new and different contexts. The field of science knowledge is vast and includes interrelated science disciplines in open inquiries and across wide-ranging context choices within guided inquiries. Therefore, teachers as well as students need to be comfortable with *not knowing.*

### *9.1.2 Possibilities for teacher and student identities within the element of digital technologies*

Findings of this study demonstrate that digital technologies in FLS environments can support a departure from traditional approaches to science learning of teacher transmission of knowledge to more personalised, student-directed approaches (Bergmann & Sams, 2014; Järvelä, 2006; Pahomov, 2014; Ruano-Borbalan, 2006). They do this by illustrating some of the ways that digital technologies can offer new options and opportunities for when, where, and how, the teaching and learning of senior secondary science can take place.

Using digital resources students were able to act as independent inquirers and to search for and find information within structured, guided, and open inquiries. These identities were especially noticeable in phase two when, for example, students used online digital resources as their primary information source to inform individual inquiries into survival in extreme environments (see section 7.2). Students were able to make choices about *where* and *when* to learn because the teacher was able to check students' progress from a distance using Google Docs as students worked in other parts of the school or at home (e.g. see section 7.2.3 and 8.3.1). That is, the online learning environment provided a virtual platform for interaction between teachers and students across space and time as work was posted and feedback received. However, this online accessibility was not always appreciated, with one teacher resenting the intrusion into their home life (section 6.5).

Digital technologies enabled students to access knowledge via a variety of online modes and media. This reinforces claims by scholars including Benade (2015b), Bergmann and Sams (2014), Bolstad and Buntting (2013), Pahomov (2014), and Wright (2017) that knowledge is no longer owned solely by teachers. Also, as suggested on the New Zealand Ministry of Education's Te Kete Ipurangi (TKI) website (Ministry of Education, n.d.-b), digital technologies can assist students to take control of their own learning, where learning objectives, content, method, and pace all may vary for each individual learner.

Digital technologies are sometimes positioned as able to render traditional teaching practices redundant (e.g. Bergmann & Sams, 2014; OECD, 2013). This claim could be seen to be consistent with some teachers' self-positioning in phase one and was especially noticeable with TT1 from school one and the HoD from school three (sections 6.1 and 6.3). These teachers experienced themselves as learning facilitators and curators of digital information rather than information transmitters. However, contrary to Ruano-Borbalan's (2006) claim that the teacher is superseded in digital environments, digital technologies did not supplant the teacher's vital role. Teachers acted as much more than mere "online educators" (OECD, 2013; p. 194). Teachers were instead repositioned as expert-enablers of digital (and other forms of) learning. Teachers used their expert knowledge to select, create, and curate online learning resources and to provide online feedback. Students also needed help to assimilate digital information and construct it as meaningful for themselves when undertaking personalised inquiries. For example, Haeata needed assistance to find science ideas at a level he could use and understand when making links to his inquiry (section 8.3.5). Further, when TT1 'flipped' the classroom using his online videos and science questions, the affordances of digital technologies were used to provide differentiated support for students when learning science concepts (section 6.1).

Digital technologies were at times the source of issues and tensions. In case study school two, teachers wanted data projectors to support traditional teacher transmission approaches using PowerPoint presentations, and it was a source of frustration when these were not available (section 6.2). While the lack of data projectors conveyed certain expectations for how *not* to teach, this on its own did not altogether stifle their efforts to enact teacher-as-expert roles as information deliverers. Sometimes teachers still used traditional whole-class sage on the stage approaches, such as when TT2 from school two defended her need to do *"board work"* with the whole class (see section 6.2.3). Sometimes the teacher-as expert and transmitter of knowledge appeared in a different way, such as in a small group workshop.

Across both phases, not all students and teachers believed technology to be necessary or helpful to learning, and as noted by Lin and Bolstad (2010), the availability of digital tools does not guarantee a shift to the use of digital pedagogies. TT1 from school three thought that using digital devices was not an effective means of helping students to achieve, as students were sometimes distracted by other online attractions. In phase two, technology sometimes distracted students and interfered with their ability to maintain task-focussed, achiever identities due to the easy availability of games and social media platforms in a manner consistent with studies by Kay et al. (2017) and Sullivan et al. (2014).

### *9.1.3 Possibilities for teacher and student identities within flexible learning spaces*

Findings from this study suggest that flexible spaces facilitate and can even enforce pedagogical innovation when teachers feel they are under pressure from the expectations of others and when physical resources support different and new practices. In school two, pressure to be innovative originated from school leadership and expectations associated with teaching in a 'new school' (section 6.2). Notable examples of teachers feeling forced to change occurred in case study schools one and three in phase one (sections 6.1 and 6.3). In school three, TT1 recognised that she needed to adjust her practice to fit a school philosophy of technology-based, student-led learning in newly-built FLS spaces. Dovey and Fisher's (2014) depiction of the irreversibility of newly built, redesigned spaces working to coerce teachers into new pedagogies is consistent with findings in these cases. While teachers and students have previously been described as unable or unwilling to adapt and take on new identities in FLS due to their own, internal, inflexible beliefs (Imms & Byers, 2017; Lackney, 2008), the constructionist view adopted in this research understands possibilities for science teacher and student identity as being both constructed and constrained externally in discourse. In this view, FLS exist as a physical outworking of the 21$^{st}$ century learning discourse, and it is acknowledged that when inhabiting the new spaces, teachers and students do what is possible for them to do, within the conditions created for them and as they apprehend these (Burr, 2003, 2015).

The FLS both required and supported some new ways of teacher collaboration. In schools one and two in phase one (sections 6.1 and 6.2) flexible spaces supported collaboration and team teaching as a way of offering different learning choices to a large group of science learners. In phase two, flexible spaces also supported teacher collaboration when the teacher was able to access different subject specialists for advice on inquiry options and allowances within NCEA assessment criteria, and for help in marking of completed achievement standards (sections 8.3.3, 8.3.5 and 8.3.6). These findings conform with Ministry of Education (n.d.-c) expectations for pedagogical innovation in flexible spaces and support Bisset's (2014) claim that a shift to flexible spaces can be accompanied by a marked change of practice for many teachers.

Flexible spaces created tensions and challenges for science teacher action associated with teacher transmission of knowledge, or what Danielsson and Warwick (2014) describe as the didactical teacher role. The teacher-as-expert in transmission mode to the whole class could not easily be enacted in the open flexible spaces. Hence, as discussed in section 9.1.2, this version of the teacher-as-expert appeared less often and in altered formats such as digital flipped learning and in small group workshops (see section 6.1, 6.2, and 7.3.1). Additionally, when the design of flexible spaces resulted in teachers being separated from equipment and demonstration materials, this altered the possibilities available for a 'good' science teacher as someone who engages in spontaneous demonstrations or practical work during teaching and discussion sessions. Although Bisset's (2014) study was not subject-specific, the notion of teachers being "charismatic front-row entertainers" (p. 75) seems especially pertinent to this science teacher identity. For some teachers, but especially for CL and TT1 from case study school one and TT1 from school three, their identity of 'good' science teacher had evolved over many years of effort and improvement, and thus was not a position that was easily abandoned. Beyond this, there seem to be contradictions within what the architectures of science spaces and 21$^{st}$ century learning spaces need to provide. Whereas FLS are open, integrated, and designed for fluidity of movement and use, science as a practical subject typically requires safe, dedicated areas furnished with specialist apparatus.

In this research there was evidence that flexible spaces authorise and support more student control and choice in learning by providing students with different options for where, and hence how and with whom to learn. These practices are in accordance with literature claiming that flexible spaces enhance possibilities for more personalised, student-centred and inquiry-based pedagogies (Cardno et al., 2014; Dovey & Fisher, 2014; Ministry of Education, n.d.-c). Additionally, flexible spaces support access to different teacher experts when strengths-based collaboration across the different disciplines of senior secondary science is required to support student inquiries (Avraamidou, 2018; Beauchamp & Thomas, 2009; Hart, 2002; Osborne, 2013). For example, in phase two, action cycle three, students undertaking self-selected structured and open inquiries were able to work in different areas and access subject specialists as required (sections 8.3.3 and 8.3.5).

### *9.1.4 Possibilities for teacher and student identities within NCEA assessment*

It was no surprise that findings from both phases of research show that NCEA as a high stakes assessment system positioned students as needing to gain credits. Teachers were positioned as accountable to the Ministry and to the school community, including students and parents, for ensuring that students achieved. Through their commentary and actions, it was possible to see the dominant and regulatory effect of accountability in high stakes assessment contexts on teacher and student identities (Søreide, 2006).

At a structural level, the flexibility in the modular NCEA matrix supported teachers as having choices that enabled them to meet the needs of their diverse students (Hipkins & Spiller, 2012). Teachers were enabled to act as orchestrators of group learning and as expert-enablers to individuals, assisting and directing many student pathways and performances of learning. These actions in turn supported options for students to develop and inhabit identities as diverse and self-directed learners. These identities were seen in action as students made decisions about which areas of science learning they would engage in and what type of assessments they would undertake (internal research or practical investigations, or external examination-based achievement standards). This finding thus supports the argument that NCEA has an inclusive orientation because it allows flexibility and choice (Absolum et al., 2009; Wylie & Bonne, 2016).

On the other hand, as discussed in chapter three, NCEA can also be "seen as a conservative force that holds back change" (Hipkins, 2015, p. 43), with the NCEA science standards not reflecting the 21st century shifts implied by the NZC (Hipkins, 2015; Hipkins et al., 2016). This research offers some insight into how and why this might be so. At the micro level of the individual achievement standards, the language used to describe each standard and to specify achievement criteria framed the way that learning was undertaken. Students were positioned into certain modes of learning and being a learner (Burr, 2003, 2015; Harré & van Langenhøve, 1999). This was seen when external achievement standards seemed to foreground conceptual knowledge, with students required to "demonstrate understanding" of specific aspects of science disciplinary knowledge (NZQA, n.d.-e) (sections 6.1, 6.2, and 6.3). For teachers, this focus on science conceptual knowledge aligned with traditional teacher-centred delivery as the practice most efficient for 'getting students through'. In other words, to support students' ability to perform in external NCEA examinations, or for students to 'show that they know', teachers relied upon identities of teacher-as-expert and transmitter of knowledge, with students positioned as recipients (Carlone et al., 2010; Tytler, 2007). Studies of assessment under NCEA in other subject areas have likewise shown that teachers will take a safe and pragmatic approach to ensuring students gain credits in NCEA (East, 2014; Gillon & Stotter, 2012).

Further to this, different and individual research and practical internal investigation standards enabled various learning choices in phase two (chapters seven and eight). In the teacher-selected research inquiries in action cycles one and two, students could choose a context for learning (see sections 7.2 and 7.3). However, when students had curious questions outside of learning specified by achievement criteria, these questions were not pursued. Therefore, students were independent inquirers in the *answering* of questions to meet criteria but not in *asking* questions (section 7.3.4).

In action cycle three it was possible to build an open inquiry around students' interests and questions, but not always easy (section 8.3.5). This was because questions or contexts needed to 'fit' the specific types of learning that the matrix of achievement standards permitted, so that learning could be assessed for credits. Tangaroa's open inquiry question 'fitted' a level three achievement standard but not at level two. Similarly, the context chosen for an open inquiry in Joseph's group at first seemed only to 'fit' into a research standard, whereas the students wanted to be practical investigators (see sections 8.3.5 and 8.3.6).

Although the teacher was willing to offer different levels of inquiry learning and although there are examples in this study of students asking their own curious questions which could be answered using a form of science inquiry, it is perhaps not surprising that findings suggest that to position themselves as independent learners and undertake an open inquiry was a challenging shift. Many instead preferred to gain credits in a safe and structured way in a teacher-directed group. The only choice these students made was to go with the guided group, and in this sense, students also acted as a 'conservative force' in the face of change (Nelson, 2014; Shier, 2006).

## 9.2 Foregrounding the multiplicity of science teacher and student identities

Others have found that teaching and learning using science inquiry involves the performance of more diverse and complex roles for both teachers and students than traditional science teaching and learning approaches (Crawford, 2000; Sharples et al., 2015; Williams et al., 2013). This study has illustrated that science teachers and students at different times and in different contexts enacted a number of different identities. In this section, and in answer to the overarching research question, I argue that these multifaceted identities were shaped by the *conditions of possibility* (Melville & Bartley, 2013; Zembylas, 2003) for pedagogical action which were created within and by the interplay between four elements of the NZC, NCEA assessment, flexible spaces, and digital technologies. I discuss the situated, synergetic, and dynamic nature of the interplay between these elements to identify a range of different identity descriptions for science teacher and student identities. I conclude that teachers and students were multiply positioned in discourses of traditional science learning where students are required to demonstrate understanding of science conceptual knowledge, and 21 century science learning as personalisation and choice within different levels of science inquiry.

To support students' learning within the disciplinary strands of the science curriculum, teachers needed to have knowledge of specific scientific concepts. Depending on the context of their particular physical space, teachers needed to find different ways of working with students to ensure that they were able to demonstrate understanding of the requisite disciplinary knowledge which was specified and assessed by NCEA, when transmission-based approaches were less possible. Teachers instead needed to adopt identities as expert enablers of group and individual, student-led learning. The affordances of digital technologies were enabling in this respect. Teachers also needed to become and be expert digital pedagogues, able to use digital technologies to assist students to learn.

To support students' learning in science inquiries, teachers needed to be knowledgeable about the overarching NoS curriculum strand and the different types and processes of science inquiry, as well as being well-acquainted with the criteria and requirements of internal investigative assessment standards in NCEA. They also needed to have current specialist and broad general science knowledge to guide students in what were possible and likely to be productive areas for exploration. On the other hand, teachers also needed to be comfortable with *not* knowing when students undertook to learn within a variety of different contexts and assessment standards. Therefore, teachers needed to be both expert-knowers *and* expert-learners about science curriculum, NCEA assessment and science inquiry.

While others have found that the balance between being a knower and a learner is a feature of teaching science inquiry (Anderson, 2002; Capps & Crawford, 2013; Prince & Felder, 2006) this study has identified a number of attributes of these identities that were related to teaching in an FLS environment. In supporting student inquiry learning, particularly when teachers did *not know*, the flexible spaces enabled teachers to easily connect with other teachers to out-source help in specialist disciplines, when and as required. Teacher identities therefore include those associated with being collaborative team teachers in flexible spaces. Easy access to digital technologies assisted students to take control of their own inquiries (Ministry of Education, n.d.-b), however, teachers needed to survey, select, manage, and oversee student access to appropriate online material. That is, they needed to be expert curators and interpreters of online resources across wide-ranging student inquiries.

At the whole-class level, teachers needed to be orchestrators of collective and individual learning. Teachers needed to be facilitators of different types of inquiry learning appropriate to differences in students' learning needs. They needed to be responsive to learners working as individuals, in small groups, or in larger groups. This sometimes necessitated the emergence of a taskmaster position as teachers set the pace and direction for learning. In all of these, aspects of teacher identity also included selecting, interpreting, and teaching aspects of curriculum, as well as ensuring, and being accountable for, student achievement in NCEA.

For students, at different times and in different contexts, a number of 21st century learner identities were associated with the personalising of learning. These included students being knowledgeable about their personal strengths, needs, and interests, and therefore able to make choices to do with when/what/where/how/why/with whom to learn.

Student identities as choice-makers relied upon the affordances and synergies created through the interplay of affordances within science curriculum, NCEA assessment, digital technologies, and physical spaces. The element of assessment was associated with student identities of being competent and successful in terms of achieving credits. Students had choices enabled by flexibility in curriculum and modular assessment design, and depending upon the achievement standard, student learner identities involved building knowledge and being knowledgeable as a "demonstrator of understanding" and being a science investigator or inquirer of various kinds. Within these different possibilities for science learning, student identities were associated with independence, self-direction, and self-management. Students were able to connect within and across flexible spaces with peers and specialist teachers who were able to assist them. Similarly, students as digital learners exploited the affordances of digital technologies as learning tools across time and space. In some open and self-selected inquiries, students were positioned as curious question-askers and investigators of science questions. However, for a number of students, experiencing themselves as independent inquirers or as the type of learner who might ask and answer their own science questions was seen as risky in terms of certainty in achieving credits in NCEA.

In sum, the traditional science schooling discourse positions teachers as experts and as deliverers of a predetermined set of increasingly complex, discipline-based concepts. Students are positioned as recipients in this knowledge exchange (Carlone et al., 2010; Tytler, 2007). A discourse of 21st century learning supports student identities of independent (yet in community), self-directed learners, with diverse needs. In this study, science teachers were still experts and students were still learners, but for both this was in an expanded and more complex sense that included identities consistent with offering and making choices in contexts of personalised learning and different levels of science inquiry. Elements of curriculum and assessment authorised choices in what, why, and how to learn. The fluidity of flexible spaces facilitated options for where, how, and with whom to learn. The affordances of digital learning tools supported choices in when, where, what, and how to learn. Of note was that those students who did not take up identities as self-directed choice-makers were then afforded less choice as students and were under tighter teacher control. Overall, however, in this research, the purposes of teaching and engaging senior students as science learners were able to shift more towards attending and answering to diverse students' needs and interests as they shaped and accomplished their learning and inquiries.

A summary of teacher and student identities associated with 21st century senior secondary science teaching and learning is included in Appendix M.

The next section will discuss limitations of this research (section 9.3).

## 9.3 Limitations

There are multiple discourses which could be associated with 'education' and with 'science schooling' (see section 2.3). In this study the focus is on influences of 21st century learning as a discourse and the possibilities it offers for the transformation of science teacher and student identities, contrasting these with possibilities offered by traditional approaches. The discourse of 21st century learning plays out in policies and practices governing curriculum and assessment which both frame and limit possibilities for pedagogical action. Flexible learning spaces and digital technologies are also elements which influence pedagogies in 21st century learning environments. However, this analysis does not take into account the range of social, emotional, cultural, or economic influences which might also be seen as characterising 21st century and traditional learning discourses. For example, it did not allow me to inquire about the influence of students' home backgrounds and the resources they provided. In the same way, although the sum of all influences within teachers' and students' social, cultural or socio-economic situations can be considered to invite certain accepted identities, this study has focused specifically on available positions which result in the performance of science teacher and student identity, that is, as something one *does* in the teaching and learning of science (see section 2.2.4).

A further limitation of the research is its small scale. In phase one data was recorded over a small window of time in level one NCEA science learning in each of three New Zealand, flexible learning space secondary schools. Given the diversity in findings across the three schools, findings for this phase cannot readily be generalised to other secondary schools. Similarly, while phase two research was conducted over a longer period of time, it was conducted in a single context with one teacher and one class in one school. Nonetheless, in striving for analytic generalisations (Yin, 2014), representations in the form of rich descriptions from multiple data sources have been provided. These are designed to enable readers to decide for themselves how and where findings may have resonance or be transferable to other contexts (Goodnough, 2011; Lawrence-Lightfoot, 2005; Merriam, 2001; Yin, 2014).

In undertaking the collaborative action research cycles in phase two, it was not possible to make a clear judgement about the impact of my role as researcher on research outcomes. I was primarily focussed on the collection of data during science sessions. There were times when I was involved as an 'extra pair of hands' in a manner which had a more tangible impact, for example, helping to record Joseph's oral assessments. I acknowledge that my continual presence in the classroom, and my attention and interest in the thoughts, actions, and progress of teacher and students had an effect.

A researcher can only frame what they observe from their own standpoint as a uniquely socially and culturally located being (Mason, 2002). While acknowledging that researcher subjectivity has shaped my noticings and interpretations, in both phases of research I have employed strategies of researcher reflexivity and participant checking. I have also presented full accounts of researcher decisions and processes to enhance trustworthiness and credibility.

## 9.4 Implications and directions for future research

In this section, implications for science teacher and learner practice and science education policy, and directions for further research are framed around the four macro-level elements. Section 9.4.1 discusses implications for curriculum and further research into the impacts of cross-curricula or cross-disciplinary inquiries on student and teacher practice. Section 9.4.2 suggests possibilities for further research in the use of digital technologies to support personalised learning. Implications for policy, design and use of physical learning spaces are discussed in section 9.4.3. Finally, implications for assessment research and suggestions for a repositioning of assessment policy and practice are discussed in sections 9.4.4 and 9.4.5.

### *9.4.1 Curriculum*

While it did not occur in this trial, it is possible that students' curious science questions and personalised investigations could evolve into a cross-disciplinary or even cross-curricular inquiry. Using the flexibility of NCEA at the structural level and the social mobility that flexible spaces permit to access different subject specialists, this is perfectly possible in theory. However, this very small study suggests this approach may attract complex issues to do with 'fit' of such inquiries to NCEA achievement standards, especially where assessment may lie across more than one standard and subject area. If large numbers of students were to undertake such inquiries there would be implications for timetabling and access to specialist teachers. As well there would be implications for structure and coherence in terms of curriculum coverage. Investigating possibilities and constraints in cross-disciplinary or cross-curricular student-directed learning on a larger scale would be an interesting and fruitful area for further research.

Teachers can strongly identify with their own particular specialist science subject, especially at the senior secondary level (Carlone, 2003; Tytler, 2010). In this research, one case study teacher introduced himself to me as *"I am Chemistry"* (section 6.1.2). The emergence of inquiry-led, cross-curricular learning is linked with new ways of collaboration and team teaching and hence would suggest challenges for subject-specific, teacher-expert identities working in transmission mode. Findings of this research suggests that teaching and learning in a 21st century personalised science learning environment involves embracing a broader range of teacher identities consistent with an expanded set of orchestrative activities needed to support diverse learners to make choices and undertake learning in various contexts at various levels of inquiry. It is therefore important that both teachers and learners are aware of these new expectations and that they benefit from personal and professional development designed to assist the explicit and intentional uptake of any expanded roles. This could include the incorporation into professional development and ITE programmes of the notion of identity as a vocabulary for thinking about aspects of science teacher and learner practice and action in 21$^{st}$ century curriculum design.

Additionally, there is scope for research which extends existing structures for personalising science learning across different contexts and grain sizes of context personalisation (Walkington & Bernacki, 2018), and across different types and levels of student-directed inquiries (Blanchard et al., 2010). Research in this area could be integrated with the development of a framework for teacher actions for scaffolding student autonomy (Patall et al., 2010) as students make choices and undertake successful learning through inquiry.

Across the three cycles of action research, guided inquiry approaches where the teacher first scaffolded and supported students' wider learning and revision before offering structured choice within a single achievement standard were most effective in terms of student achievement in NCEA. This finding aligns with Bamberger and Tal's (2007) analysis of levels of choice where limited or structured choices were associated with highest interest and motivation as well as learning gains. Further research could examine the possibilities and benefits of students first learning foundational concepts in a chosen area before extending their learning into an aspect of self-chosen or more open inquiry under NCEA. In other words, *knowing about* science would be for the purpose of later *not knowing* and asking curious questions.

The fragmentation of curriculum into discrete pockets of scientific knowledge which can be separately assessed is both a strength and a weakness (Jones & Buntting, 2013, and see section 3.4). Offering the option of personalising learning within any available NCEA achievement standards could lead to a lack of coherence in curriculum and be critiqued as enlisting arbitrary approaches to learning in the form of credit collection. Similarly, the issue of curriculum fragmentation highlights tensions between student choice in curriculum content and the necessity of teaching foundational, generative concepts (McPhail, 2016). For some students who want to pursue science-related careers, science learning needs to be conceptually coherent in the form of development of ever-deeper disciplinary knowledge. For other students, deep disciplinary knowledge might be subsidiary to coherence in the learning and development of increasingly complex science skills and capabilities associated with undertaking and communicating the outcomes of research and inquiries. This raises questions about the types and meanings of curriculum coherence that should or could be valued, and for whom, in science teaching, learning and assessment. When science knowledge is extensive, expanding, changing, and accessible online, and where all citizens need to be scientifically literate, what kind of knowledge-building and curriculum coherence is legitimate and useful?

### *9.4.2 Digital technologies*

In this research, digital technologies and web-based document-editing applications such as Google Docs were used to enable teachers to give feedback on work and to track students' progress (section 7.2.3). The teacher's role in tracking, monitoring, and mentoring many students on individualised paths is essential to support student progress in personalised learning. Hence, an area for further investigation and development is ways in which digital tools and technologies might support this complex task. For example, research could inquire into the use of voice recording technology to capture conversations where formative feedback is given to students by the teacher.

Customised online science websites and learning platforms designed specifically for science education can support the learning and revision of disciplinary and conceptual knowledge as well as supporting students to find information for individual inquiries (Education Perfect, 2017; University of Waikato, 2018). However, not all students and teachers capitalised on the affordances that online digital technologies offer (see sections 6.3, 7.3.5, and 8.3.6). Another area for close investigation could be a mixed-methods study into "technology as teacher" in NCEA science. How and why does technology support or not support science learning, and what types of learner and learning does it support or not support? Does technology-based, online learning improve student achievement where students opt into this type of learning? Is this more, or less successful than teacher-transmission and workbook-based learning, and for whom?

### *9.4.3 Flexible learning spaces*

This research has highlighted new implications for the use of flexible spaces associated with senior science learning. The configuration of physical spaces as well as resourcing for science as a subject impacted the frequency and spontaneity of teacher demonstrations and practical work undertaken in this study. Therefore, a central question for science as a practical subject is around what design of specialist areas is agile enough to enable staff and students to work safely in personalised and fluid ways, yet still allow the teacher as charismatic entertainer or demonstrator to spontaneously emerge and ignite students' interest or reinforce conceptual understanding. Further study could involve investigation into the usability in terms of flexibility, safety, and accessibility of a wide range of learning space designs and resourcing for practical work in science education. A further implication is the need for the inclusion of teacher and student voice in the initial design stages of school rebuilds, and especially where subject areas such as science require safe, dedicated practical areas furnished with specialist apparatus.

Another issue raised by the study relates to physical space and the types of teacher identity that different flexible spaces enable, or even require. Working in shared spaces impacted teachers' abilities to practice as they wanted to. Shared spaces also influenced teachers' feelings of ownership of students as 'my class', and increased teacher stress levels. The teachers in the study had not always been supported in making the transition to flexible spaces. One implication of this is the need for resources, professional learning programmes, and practicum experiences which support the development of preservice teachers' practice in flexible learning spaces. As well, support is needed for experienced teachers in making the transition to teaching and learning in open, shared, flexible spaces. This includes planning to use space collaboratively to support students to learn.

### *9.4.4 Assessment*

A major area for research, and not a focus in this study, is the assessment of key competencies and capabilities in science. These are detailed in the NZC and in the NoS strand of science curriculum but not explicitly assessed under NCEA. Internationally, work has been done in this area (Adamson & Darling-Hammond, 2015; Griffin & Care, 2015). Further research into the definition and assessment of 21st century skills and competencies in science, and further work around how these skills could be meaningfully assessed within NCEA as a high stakes senior school exit qualification would be useful.

Another important area for further research and uncovered by this study is an in-depth investigation into the language used in descriptions of achievement standards and achievement criteria. Findings in this study suggest that the language of achievement standards impacts the type of learning enacted. For example, if students are required to “demonstrate understanding” of science knowledge, how are students being positioned in their learning? What does this *not* enable them to do and be as learners? Do the words “demonstrate understanding” position students as active participants in using, interacting with, and producing science knowledge, or are they positioned by this language more as consumers and reproducers? How does the language in achievement standards position teachers? The subject identity produced by the language of science standards, and the types of identities constructed for teachers and students, would be an interesting area for further study given the new possibilities identified in this study.

#### *9.4.5 Repositioning teachers and students within science assessment*

As has been found elsewhere (e.g. Hart, 2002; Søreide, 2006), findings suggest that assessment exerts a dominant influence in shaping science learning and associated teacher and student identities. As suggested in 9.4.4 above, one implication of this is that if NCEA science achievement standards were further developed, and worded differently, they might support different types of teacher and student identities that could take different advantage of affordances offered by flexibles spaces, digital technologies, and a framework curriculum.

An example of an opening for the repositioning of teachers and students within NCEA assessment could be more provision within the wording of some achievement standards to encourage and reward students who ask their own questions, who undertake more open inquiries, and who are curious within science knowledge contexts in their own way. This might go some way towards broadening the meaning of a ‘good’ science student to include someone who is curious and asks good questions (Carlone, 2012), perhaps enabling science to be more accessible for diverse students who are very differently socially and culturally located. Similarly, and as discussed in section 9.4.4 above, if 21st century skills and competencies are to be valued then provision needs to be made within standards for these to be explicitly assessed and credentialed.

Another example of an opening for the repositioning of science teachers and students within NCEA assessment can be found in section 8.3.5, where criteria in the biology investigation standard permitted students to work in collaborative groups while designing their investigation and collecting data but expected students to make meaning from their results and demonstrate understanding in written discussions on their own. Noting student J's motivation and involvement during his time as group member, I wondered about his eventual end result in terms of credits should he have been permitted by the assessment criteria to continue as part of a group, who socially constructed knowledge from their findings during the write-up (Carlone, 2003).

## 9.5 Conclusion

This research set out to explore ways in which the discourse of 21st century learning might influence notions of senior secondary science to reposition teachers and students of science in Aotearoa New Zealand.

Findings of this research show how the multifaceted identities taken up by teachers and students of senior science were shaped by the pedagogical possibilities created and available within the dynamic interplay between four elements of the NZC, NCEA assessment, flexible spaces, and digital tools and technologies. Teachers and students could be seen to be positioned by, and to position themselves within a discourse of 21st century learning related to personalisation and student choice, *and* the discourse of traditional science schooling. Tensions were visible in what teachers and students could do and chose to do, what they wanted or tried to do, and what they did not do.

Some aspects of NCEA assessment acted to strengthen the traditional science schooling discourse and foreground science as knowledge-based, and hence to support identities of teacher-expert and transmitters of knowledge, and students as receivers. Other aspects of NCEA provided openings in line with science as inquiry as advocated in the NZC. Some aspects of FLS environments did not support some teachers' view of traditionally effective approaches to science teaching and practical work. However, the affordances of digital tools and technologies and the fluidity and social flow of flexible spaces enhanced possibilities for many forms of learning choices. Flexible spaces also supported team teaching of larger groups and collaboration of teachers across science disciplines.

Teachers responded to these openings by scaffolding different types of learning choices for diverse senior students in relation to what, why, where, how, and with whom students could learn. Teachers offered and supported student learning within different contexts and at different levels of openness of science inquiry. However, some students did not take up the full scope of the opportunities offered, especially where these opportunities were not fully supported by, or were in tension with, students' ideas of how best to be competent and successful in terms of achieving credits in NCEA. Findings show that more personalised science learning using context choice and different levels of openness of science inquiry is possible in FLS in high stakes assessment environments. However, it is sometimes difficult. In the observable reality of life in senior science classrooms, teachers and students do what they view as possible and likely to be beneficial for them to do within conditions created by the interplay of elements of FLS, curriculum, assessment, and digital technologies. The teacher's role is central in scaffolding student autonomy to make choices and to undertake, complete, and achieve in student-directed inquiries. Overall, and in spite of the challenges and tensions that teachers and students faced, this research identifies opportunities for broadening the definition of 'good' science teacher and learner to include the offering and uptake of a range of learning choices in senior science inquiry.

This research has contributed insights in the form of situated stories of people and place. It documents the struggles and achievements of teachers and students: what *was* happening and what *did* happen as they were positioned and as they acted to reposition themselves to take on different science teacher and learner identities in contexts of high stakes NCEA science assessment in 21$^{st}$ century FLS environments.

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# Appendices

## *Appendix A: Matrix of level one science achievement standards*

| *Matrix of level one science achievement standards* (NZQA, n.d.-e) | | | |
|---|---|---|---|
| *Physical World* (*Physics*) | *Material World* (*Chemistry*) | *Living World* (*Biology*) | *Planet Earth & Beyond* (*Earth and space science*) (*ESS*) |
| AS90940<br>Science 1.1<br>Demonstrate understanding of aspects of mechanics<br>4 credits<br>External | AS9094<br>Science 1.5<br>Demonstrate understanding of aspects of acids and bases<br>4 credits<br>External | AS90948<br>Science 1.9<br>Demonstrate understanding of biological ideas relating to genetic variation<br>4 credits<br>External | AS90952<br>Science 1.13<br>Demonstrate understanding of the formation of surface features in New Zealand<br>4 credits<br>Internal |
| AS90941<br>Science 1.2<br>Investigate implications of electricity and magnetism for everyday life<br>4 credits<br>Internal | AS90945<br>Science 1.6<br>Investigate implications of the use of carbon compounds as fuels<br>4 credits<br>Internal | AS90949<br>Science 1.10<br>Investigate life processes and environmental factors that affect them<br>4 credits<br>Internal | AS90953<br>Science 1.14<br>Demonstrate understanding of carbon cycling<br>4 credits<br>Internal |
| AS90942<br>Science 1.3<br>Investigate implications of wave behaviour for everyday life<br>4 credits<br>Internal | AS90946<br>Science 1.7<br>Investigate the implications of the properties of metals for their use in society<br>4 credits<br>Internal | AS90950<br>Science 1.11<br>Investigate biological ideas relating to interactions between humans and micro-organisms<br>4 credits<br>Internal | AS90954<br>Science 1.15<br>Demonstrate understanding of the effects of astronomical cycles on planet Earth<br>4 credits<br>Internal |

| | | | |
|---|---|---|---|
| AS90943<br>Science 1.4<br>Investigate implications of heat for everyday life<br>4 credits<br>Internal | AS90947<br>Science 1.8<br>Investigate selected chemical reactions<br>4 credits<br>Internal | AS90951<br>Science 1.12<br>Investigate the biological impact of an event on a New Zealand ecosystem<br>4 credits<br>Internal | AS90955<br>Science 1.16<br>Investigate an astronomical or Earth science event.<br>4 credits<br>Internal |
| AS90935<br>Physics 1.1<br>Carry out a practical physics investigation that leads to a linear mathematical relationship, with direction<br>4 credits<br>Internal | AS90930<br>Chemistry 1.1<br>Carry out a practical chemistry investigation, with direction<br>4 credits<br>Internal | AS90925<br>Biology 1.1<br>Carry out a practical investigation in a biological context, with direction<br>4 credits<br>Internal | |
| AS90936<br>Physics 1.2<br>Demonstrate understanding of the physics of an application<br>2 credits<br>Internal | AS90931<br>Chemistry 1.2<br>Demonstrate understanding of the chemistry in a technological application<br>2 credits<br>Internal | AS90926<br>Biology 1.2<br>Report on a biological issue<br>3 credits<br>Internal | There are exclusions between:<br>Sci 1.2 and Phys 1.3<br>Sci 1.3 and Phys 1.4<br>Sci 1.4 and Phys 1.5<br>Sci 1.6 and Chem 1.3<br>Sci 1.7 and Chem 1.4<br>Sci1.8 and Chem 1.5<br>Sci1.11 and Bio 1.3 |
| AS90937<br>Physics 1.3<br>Demonstrate understanding of aspects of electricity and magnetism<br>4 credits<br>External | AS90932<br>Chemistry 1.3<br>Demonstrate understanding of aspects of carbon chemistry<br>4 credits<br>External | AS90927<br>Biology 1.3<br>Demonstrate understanding of biological ideas relating to micro-organisms<br>4 credits<br>External | |

| | | |
|---|---|---|
| AS90938<br>Physics 1.4<br>Demonstrate understanding of aspects of wave behaviour<br>4 credits<br>External | AS90933<br>Chemistry 1.4<br>Demonstrate understanding of aspects of selected elements<br>4 credits<br>External | AS90928<br>Biology 1.4<br>Demonstrate understanding of biological ideas relating to the life cycle of flowering plants.<br>4 credits<br>External |
| AS90939<br>Physics 1.5<br>Demonstrate understanding of aspects of heat<br>4 credits<br>External | AS90934<br>Chemistry 1.5<br>Demonstrate understanding of aspects of chemical reactions<br>4 credits<br>External | AS90929<br>Biology 1.5<br>Demonstrate understanding of biological ideas relating to a mammal(s) as a consumer(s)<br>3 credits<br>External |

*Appendix B: Matrix of level two science achievement standards*

| *Matrix of level two science achievement standards (NZQA, n.d.-e)* | | | |
|---|---|---|---|
| *Physical World (Physics)* | *Material World (Chemistry)* | *Living World (Biology)* | *Planet Earth and Beyond (Earth and space science) (ESS)* |
| AS91168<br>Physics 2.1<br>Carry out a practical physics investigation that leads to a non-linear mathematical relationship<br>4 credits<br>Internal | AS91161<br>Chemistry 2.1<br>Carry out quantitative analysis<br>4 credits<br>Internal | AS91153<br>Biology 2.1<br>Carry out a practical investigation in a biology context, with supervision<br>4 credits<br>Internal | AS91187<br>ESS 2.1<br>Carry out a practical earth and space science investigation<br>4 credits<br>Internal |
| AS91169<br>Physics 2.2<br>Demonstrate understanding of physics relevant to a selected context<br>3 credits<br>Internal | AS91162<br>Chemistry 2.2<br>Carry out procedures to identify ions present in solution<br>3 credits<br>Internal | AS91154<br>Biology 2.2<br>Analyse the biological validity of information presented to the public<br>3 credits<br>Internal | AS91188<br>ESS 2.2<br>Examine an earth and space science issue and the validity of the information communicated to the public<br>4 credits<br>Internal |
| AS91170<br>Physics 2.3<br>Demonstrate understanding of waves<br>4 credits<br>External | AS91163<br>Chemistry 2.3<br>Demonstrate understanding of the chemistry used in the development of a current technology<br>3 credits<br>Internal | AS91155<br>Biology 2.3<br>Demonstrate understanding of adaptation of plants or animals to their way of life<br>3 credits<br>Internal | AS91189<br>ESS 2.3<br>Investigate geological processes in a New Zealand locality<br>4 credits<br>Internal |
| AS91171<br>Physics 2.4<br>Demonstrate understanding of mechanics<br>6 credits<br>External | AS91164<br>Chemistry 2.4<br>Demonstrate understanding of bonding, structure, properties and energy changes<br>5 credits<br>External | AS91156<br>Biology 2.4<br>Demonstrate understanding of life processes at the cellular level<br>4 credits<br>External | AS91190<br>ESS 2.4<br>Investigate how organisms survive in an extreme environment<br>4 credits<br>Internal |

| | | | |
|---|---|---|---|
| AS91172<br>Physics 2.5<br>Demonstrate understanding of atomic and nuclear physics<br>3 credits<br>Internal | AS91165<br>Chemistry 2.5<br>Demonstrate understanding of the properties of selected organic compounds<br>4 credits<br>External | AS91157<br>Biology 2.5<br>Demonstrate understanding of genetic variation and change<br>4 credits<br>External | AS91191<br>ESS 2.5<br>Demonstrate understanding of the causes of extreme Earth events in New Zealand<br>4 credits<br>External |
| AS91173<br>Physics 2.6<br>Demonstrate understanding of electricity and electromagnetism<br>6 credits<br>External | AS91166<br>Chemistry 2.6<br>Demonstrate understanding of chemical reactivity<br>4 credits<br>External | AS91158<br>Biology 2.6<br>Investigate a pattern in an ecological community, with supervision<br>4 credits<br>Internal | AS91192<br>ESS 2.6<br>Demonstrate understanding of stars and planetary systems<br>4 credits<br>External |
| | AS91167<br>Chemistry 2.7<br>Demonstrate understanding of oxidation–reduction<br>3 credits<br>Internal | AS91159<br>Biology 2.7<br>Demonstrate understanding of gene expression<br>4 credits<br>External | AS91193<br>ESS 2.7<br>Demonstrate understanding of physical principles related to the earth system<br>4 credits<br>External |
| | | AS91160<br>Biology 2.8<br>Investigate biological material at the microscopic level<br>3 credits<br>Internal | |

## *Appendix C: Phase one Principal information letter and consent form*

… June 2016

Dear [Name]

I am a full time doctoral student at University of Waikato and am I seeking your permission to conduct research at your school. I am an experienced science/chemistry teacher and for the past 6 years have worked as a secondary teacher educator.

I am interested in finding out about teaching, learning, and assessment in science in a modern learning environment (or innovative learning space (ILS)). In particular I am interested in how NCEA science assessment functions in an ILS to allow or disallow principles of 21$^{st}$ century learning, for example, student-centred, inquiry-based learning.

During the first stage of the research I hope to observe level one science classes from different schools working in ILS environments and interview selected teachers and students about the teaching/learning taking place.

Should you agree to this research, I would first approach science teachers in your school to ask them to consider participating in the study. The research would take place between July and October 2016 and will involve:

- Observation and audio/video recording of science learning with one level one science class over one/two weeks (up to 4 sessions)
- Teacher/s of the class taking part in two audio-recorded semi-structured interviews (no more than one hour each) at a mutually agreeable time/place. The second interview will be to give the teacher opportunity to check and discuss any data collected.
- Students being informally interviewed by the researcher about their learning ‘in the moment’, during class time (brief, audio-recorded, conversational interactions no more than 2-3 minutes each)

Informed consent would be sought from all participants before commencement of research. Teachers will be provided with copies of interview transcripts and observation notes for review. During the second interview I will ask the teacher for confirmation that these notes and transcripts may be used in the research. Teachers have the right to withdraw from the research at any stage up until this confirmation is given. Individual consent will be sought from each student and consent will also be sought from parents/guardians/whānau for students under 16 years of age. Students have the right to decline to participate in the research or to withdraw from the research at any stage.

The research project has been approved by the University of Waikato’s Faculty of Education Ethics Committee and will be conducted under the supervision of Professor Bronwen Cowie from the University of Waikato, Faculty of Education. The primary function of the research is for use in a thesis for a PhD degree at the University of Waikato. It is also possible that the findings of the research may provide the basis for academic journal articles, educational seminars, oral presentations and conferences at the outset of the research project. While every effort will be made to ensure anonymity for the school, teachers, and students, this cannot be guaranteed. However, confidentiality will be maintained and no school or person will be named or identified in any way in the thesis or subsequent publications/presentations.

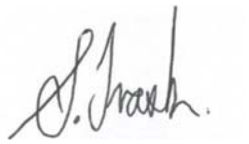
If any disputes, concerns, or questions arise, participants will be encouraged to contact myself as researcher in the first instance. Otherwise they can contact my supervisor, Professor Bronwen Cowie, using the contact details below.

I am very happy to provide you with a short report on useful findings of this first stage of the research and to share these with staff at your school. I will also provide you with an electronic copy of the final thesis once it has been completed, should you request this on the consent form.

If you have any further questions, please contact me using the contact details below.

Thank you for your time, and I look forward to your response.

Yours sincerely,



Suzanne Trask

Principal Consent Form

| | |
|---|---|
| **Research title:** | Repositioning students and teachers for science assessment in 21st century learning environments. |
| **Researcher:** | Suzanne Trask. Doctoral student, University of Waikato. |

- I give permission for the research as outlined in the introductory letter to be conducted in [Name] High School/College.
- I agree the information gathered in this study may be used for future research, publications, and/or presentations, and that under no circumstances will names, identities or any personal details be shared with anyone else.
- I would like an electronic copy of the thesis, once it is completed. YES/NO

| | | |
|---|---|---|
| Principal | Date | Signature |
| Researcher | Date | Signature |

## *Appendix D: Phase one teacher information letter and consent form*

…. June 2016

Dear [Name]

I am a full time doctoral student at University of Waikato. I am also an experienced science/chemistry teacher and for the past 6 years have worked as a secondary teacher educator.

I am interested in finding out about teaching, learning, and assessment in science in a modern learning environment (or innovative learning space (ILS)), and I am seeking your consent to being a participant this research.

Many teachers are working to identify and exploit the potential of the NCEA assessment system in ILS environments, yet not much is known about how NCEA science achievement standards allow or disallow principles of 21st century learning such as student-centred inquiry, or how NCEA science assessment functions in an ILS.

During the first stage of the research I hope to observe level one science classes from different schools working in ILS environments and interview a small number of teachers and students about the teaching/learning taking place. If you consent to taking part in this research it would take place between July and October 2016 and will involve:

- Observation and audio/video recording of science learning, following one level one science class for one week
- Two semi-structured interviews (no more than one hour each, which will be audio-recorded with your permission) at a mutually agreeable time/place. Part of your involvement in the research will be to read and review your interview transcript and a summary of observation notes and discuss these with me during the second interview
- The students from the level one science class being informally interviewed by me about their learning 'in the moment', during class time (brief, audio-recorded, conversational interactions no more than 2-3 minutes each)

The research project has been approved by the University of Waikato's Faculty of Education Ethics Committee and will be conducted under the supervision of Professor Bronwen Cowie from the University of Waikato, Faculty of Education. The primary function of the research is for use in a thesis for a PhD degree at the University of Waikato. It is also possible that the findings of the research may provide the basis for academic journal articles, educational seminars, oral presentations and conferences at the outset of the research project. While every effort will be made to ensure anonymity for the school, teachers, and students, this cannot be guaranteed. However, confidentiality will be maintained, and no school or person will be named or identified in any way in the thesis or subsequent publications/presentations.

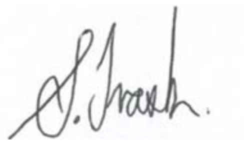
If you agree to take part in the study you have the right to withdraw your participation without providing a reason at any stage, up until the time you have reviewed and confirmed lesson notes and interview transcripts during the second interview. To withdraw from the project, you will simply need to notify me verbally or in writing. You can also decline to answer any questions and/or to have data collected on you at any particular time.

If any disputes, concerns, or questions arise during the research, I can be contacted at any time using the contact details below. Otherwise, please contact my supervisor, Professor Bronwen Cowie.

I am very happy to discuss and share with you a short report on useful findings of this first stage of the research. I will also provide you with an electronic copy of the final thesis once it has been completed, should you request this on the consent form.

If you have any further questions, please contact me using the contact details below. I look forward to your response.

Yours sincerely,



Suzanne Trask

Teacher Consent Form

| | |
|---|---|
| **Research title:** | Repositioning students and teachers for science assessment in 21$^{st}$ century learning environments. |
| **Researcher:** | Suzanne Trask. Doctoral student, University of Waikato. |

- I confirm that I have read and understood the invitation letter for the research project above and have had the opportunity to ask questions.
- I agree to take part in the research project as outlined in the invitation letter.
- I understand that my participation is voluntary, and that I may withdraw at any time if I am uncomfortable with something I said being recorded.
- I agree the information gathered in this study may be used for future research, publications, and/or presentations, and that under no circumstances will names, identities or any personal details be shared with anyone else.
- I understand that if I have any concerns about the research I can talk to the researcher, or if I prefer, I can contact Professor Bronwen Cowie (contact details are below).
- I would like an electronic copy of the thesis, once it is completed. YES/NO

| ____________ | ____________ | ____________ |
|---|---|---|
| Teacher | Date | Signature |
| Researcher | Date | Signature |

## *Appendix E: Phase one student information and consent letter*

… August 2016

Dear students of Year 11 Science

My name is Suzanne Trask. I am a full time PhD student at University of Waikato and am also an experienced science teacher.

As part of my research for my PhD I am interested in finding out about teaching, learning, and assessment in science in a modern learning environment (or innovative learning space). I hope to find out more about how NCEA science assessment works in schools such as yours where learning happens in open, innovative learning spaces. This letter is to invite you to take part in my research.

The Acting Principal and the HoD Science, along with your science teachers, have agreed to allow me to spend time in your science class observing. With your permission, I would also like to talk to you about your work – just brief chats during class time - and audio-record your responses. As well I would like to use a video camera to record the learning in your class.

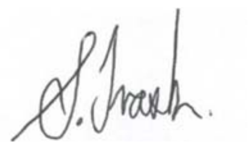
It is important you know that I will be in your class as a researcher not a teacher, and I will not be judging you or your work in any way. My goal is to hear your thoughts about being a learner in an innovative learning space. It is important to understand you do not have to participate in this study. If you decline to participate this means that I will not talk with you or ask to look at your work. Even if you agree to participate in my research you can tell me not to talk to you on a particular day/ time. For example, if I ask you a question you do not have to answer it. If I ask to see your work, you do not have to show me. You may withdraw your participation in the study as a whole any time by telling me you want to do this and/or writing me a note. If you choose to withdraw I will not use any information about you or from you in the study or collect any data on you once you have withdrawn.

You will not be personally identified in the study, neither will your school nor any person at the school. Anything you discuss with me will remain confidential. The information I gain from this study will be used in my PhD project and may also be used in an article in an academic journal or in a presentation. I will not identify you or your school in any way in any of these.

If you agree to participate in the study please complete the consent form attached and give it to your teacher. If you have any questions that you think I have not answered you can ask me or my supervisor, Bronwen Cowie. We can be contacted using the details below.

I look forward to your response.

Yours sincerely,



Suzanne Trask

Student Consent Form

You are making a decision whether or not to participate in the research project as outlined in the invitation letter. Your signature indicates that you have decided to participate in the research project.

**Title:** Repositioning students and teachers for science assessment in 21st century learning environments.

**Researcher:** Suzanne Trask. Doctoral student, University of Waikato.

- I confirm that I have read and understood the invitation letter for the research project above and have had the opportunity to ask questions.
- I agree to take part in the research project as outlined in the invitation letter.
- I understand that my participation is voluntary, and that I may withdraw at any time if I am uncomfortable with something I said being recorded.
- I agree the information gathered in this study may be used for future research, publications, and/or presentations, and that under no circumstances will names, identities or any personal details be shared with anyone else.
- I understand that if I have any concerns about the research I should talk to my teacher or I can contact the researcher, or if I prefer, I can contact Professor Bronwen Cowie (contact details are below).

| ______________ | ______________ | ______________ |
| --- | --- | --- |
| Student | Date | Signature |
| ______________ | ______________ | ______________ |
| Researcher | Date | Signature |

## *Appendix F Phase one parent information and consent letter*

Dear Parents/Whānau/Guardians of students in Year 11 Science,

My name is Suzanne Trask. I am a full time doctoral student at University of Waikato and am also an experienced science teacher and teacher educator.

As part of my PhD research I am interested in finding out about teaching, learning, and assessment in science in a modern learning environment (or innovative learning space (ILS)). I hope the research will provide insight into ways teachers and students work together in ILSs when focussed on NCEA assessments

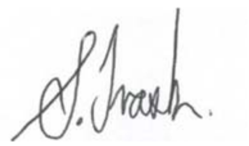
I have the Principal's and HoD science's consent to spend time in your son/daughter's science class observing (up to 3 sessions). With your permission I would also like to talk to the students in the class about their work (brief 2 or 3 minute conversations) and audio-record their responses. As well I would like to use a video camera to record the teaching, learning, and interactions between teacher and students.

The research project has been approved by the University of Waikato's Faculty of Education Ethics Committee and will be under the supervision of Professor Bronwen Cowie from the University of Waikato, Faculty of Education. Your son/daughter has the right to refuse to answer any particular question or to refuse to participate in the study at all.

The research is for use in a thesis for a PhD degree at the University of Waikato. It is also possible that the findings of the research may form part of a publication in an academic journal or may be used in a presentation. Confidentiality will be maintained and no person will be named or talked about in any way outside of the research. Neither will any person will be named in any way in the thesis or other publication/presentation.

If you have any further questions, please contact me using the contact details below. I look forward to your response.

Yours sincerely,



Suzanne Trask

Parent Consent Form

| | |
|---|---|
| **Research title:** | Repositioning students and teachers for science assessment in 21st century learning environments. |
| **Researcher:** | Suzanne Trask. Doctoral student, University of Waikato. |

- I have read and understood the invitation letter for the research project above and have had the opportunity to ask questions.
- I agree to my son/daughter taking part in the research project as outlined in the invitation letter.
- I understand that participation is voluntary, and that my son/daughter may withdraw at any time.
- I agree the information gathered in this study may be used for future research, publications, and/or presentations, and that under no circumstances will names, identities or any personal details be shared with anyone else.
- I understand that if I have any concerns about the research I can talk to my son/daughter's teacher or I can contact the researcher. If I prefer, I can contact Professor Bronwen Cowie (contact details are below).

| | | |
|---|---|---|
| Parent/Whānau/Guardian | Date | Signature |
| Researcher | Date | Signature |

## *Appendix G: Sample teacher semi-structured interview process and questions phase one*

**Setting the stage**

(Kvale & Brinkmann, 2009, p. 128)

Thank you and appreciation for time, contribution to knowledge etc.

Are you comfortable with me using a recorder? Refer to Consent – you will have access to transcript, anything you don't want used will not be used etc. I will take a few notes during the interview, just to help me remember to ask you about something in greater depth/so we can return to something if needed.

No more than one hour – will honour that. If need a break, let me know.

**Briefing**

(Kvale & Brinkmann, 2009, p. 128)

I want to find out about your experiences of being a science of NCEA classes in an FLS. Also, what science learning looks like/is like in an FLS, especially when students are working towards NCEA assessments. Focussed on level one science.

Explain: This is phase one of the study. Signal: Phase two, action research, trial something new with one school.

**Interview questions**

**Teacher and learner information**

Could you tell me a little bit about your background as a science teacher and about your role now? (Teacher self-positioning/teacher identity)

> Possible prompts: has role changed, do you see yourself differently as a teacher now compared to then, how do you think the students see you as teacher?

Could you tell me a little about the learners in your level one science class? (Second order positioning – how teacher sees students)

> Possible prompts: as a group, group dynamics, individual identities influencing, perceived capabilities, perceived futures

How does being in an FLS affect what you do?

***Science learning***

What do you see as goals of level one science learning? (How teacher positions subject)

> Possible prompts: compared to science in society/industry/community, as career, for citizenship, develop capabilities/competencies such as problem solving, enjoyment/interest, entry to levels 2 and 3, as part of 'good' education, role of NoS, NZC, KCs

How do you think your students learn best? Tell me how you prefer to work with students to support their learning? (Who should 'teacher' be, who is a 'student'?)

> Possible prompts: may be different for each individual, for externals compared with internals, what if we took any high stakes assessment considerations out of the picture – then how would you choose to teach, group learning, direct teaching, inquiry, digital environment

Could you tell me about the level one science programme in your school? (Institutional discourse: How do learners engage with the subject as teachers and learners)

> Possible prompts: which achievement standards do you choose to use and how/why, how plan the year, student participation on programme design, engagement with contemporary science practice (Bolstad & Buntting, 2013, p. 13), how deliver externals vs internals, inquiry, allowances for UE and vocational pathways, formal face-to-face teaching, flexibility/personalisation, cross-curricular or theme-based learning, role of NoS, role of digital technology/digital pedagogies

One of the principles of NZC (and in ideas of 21st century learning) is personalised learning. To what extent are you able to personalise learning for students in level one science? And how do you accomplish? Do you need to personalise? What are benefits/disadvantages/barriers?

Describe a typical session – is there one?! What affordances are there in an FLS that weren't there in a traditional classroom?

Describe an atypical session

Describe the best moments with this class in learning

***Science assessment***

What do you see as the purposes of level one science assessment *(may already have been covered by earlier questions –whether they see assessment as learning and more formative, as gaining credits, as base for Levels 2 and 3, whether they see as necessary at all).*

In your view, what ways do NCEA achievement standards allow students to demonstrate/ restrict student demonstration of their learning? What do you see as your role in each of these aspects?

How are choices made around which achievement standards to use and which not and why? What influences your decisions? What happens to the learning 'left out'?

How have you taken advantage of the NCEA assessment system to plan to best suit each individual learner?

Do thoughts of preparing students for assessments impact what you do in the classroom? If so, in what ways? (Does assessment lead the learning, to what extent)

> Possible prompts: compare internal and external achievement standards. For example, how do you approach teaching and learning in the chemistry investigation internal? Compared with the acids and bases external?) If removed assessment considerations, how would you teach?

What do assessment results tell us about students' learning? Informal-summative-formative diagnostic.

> Possible prompts: for internal summative – should students know what grade they will receive as they hand the work in i.e. how much of a part does formative assessment play in internal achievement standards – have you worked so closely with student during their internal that you (and they) know the grade they will get before you mark it. Or not?
>
> Ideas of assessment capability

***Future thinking***

Are you thinking of making changes to your programme? Why/why not? How?

Possible prompts: What types of science learning and assessment would best support individual student achievement in an FLS? Are there any assessment formats within NCEA that are possible, but that perhaps are not used? Can you tell me what some of these might be and why they might not be used?

***Debriefing***

Thanking, anything more to say? Ask about their experience of the interview.

What will happen from here (I transcribe, send you transcription for checking etc, come back for second interview to discuss themes, check aspects of my interpretation).

***Appendix H: Examples of thematic and discourse analysis***

Examples of thematic and discourse analyses from phases one and two are presented below.

***Student interview example one:***

Phase one/school 2/student S4:

> *Researcher (Speaking to student S4 who has moved out of the science learning area and into the adjoining open commons. He is sitting on his own, on the floor): Do you mind telling me a little bit about what you're doing, and why you've chosen to come out here...?*
>
> *S4: Just…it's more quiet, and so I can actually do some work, and not get distracted by everyone.*

| Thematic analysis | *Element* | *Theme* | *Categories* |
| --- | --- | --- | --- |
| | Space | Affordances of flexible space | Student movement across spaces |
| | | | Learning choices Student can choose where to learn |
| | | Challenges to do with flexible space | Noise |
| | | | Distractibility |

| Discourse analysis: | *Element* | Space |
| --- | --- | --- |
| | *Conditions of possibility* | Open spaces enable flexibility and movement |
| | *Positioning* | Student has a duty to get work done. Student wanted to be able to work without distraction caused by noise. Students are permitted to move across spaces and can make choices about where to work. Student took up the right to move across space to sit by himself on the floor. |
| | *Identity* | Self-directed, self-managed learner |

| | | |
|---|---|---|
| | *Identity within discourse* | 21st century learner |

***Student interview example two:***

Phase two/week 9/term 2/student L

> *Students have been offered the option of open inquiry-based learning in action cycle three.*
>
> *Researcher to student L: Do you have any ideas about what you could or would do?*
>
> *Student L: We get to come up with our own project ourself? And it has to relate to science? ... I'd go for skateboarding and physics and look at the way physics is applied to the skateboard. But it depends how many credits. It would need to be a decent amount of credits."*

| Thematic analysis | *Elements* | *Theme* | *Category* |
|---|---|---|---|
| | Assessment | High stakes assessment driving behaviour | Credit collecting by student |
| | | Internal achievement standards | Learning choices Flexibility in assessment Student can choose what to learn |
| | Curriculum | Framework curriculum | Learning choices Students can choose what to learn<br>Flexibility in curriculum |

| Discourse analysis | *Elements* | Curriculum and assessment |
|---|---|---|
| | *Conditions of possibility* | Modular NCEA assessment and framework curriculum enable open inquiry |

| | | |
|---|---|---|
| | *Positioning* | Student is offered choices of what to learn and wants to choose the physics of skateboarding, however, the student has a duty to achieve and modular NCEA assessment results in a focus on credit collecting. |
| | *Identity* | Student prioritises the position of achiever/credit collector in NCEA. |
| | *Identity within discourse* | Tension between 21st century learner and traditional achievement |

**Teacher interview example one:**

Phase one/school 3/CL first interview

> *CL: You can't as a teacher now, deliver information. There's no point, cos students can get that information at the push of a button…so if you're trying to deliver information you're fighting with the students and you're fighting with technology. It's not your role anymore…there is maybe a role for curation of information, but not…(delivery).*

| Thematic analysis | *Element* | *Theme* | *Category* |
|---|---|---|---|
| | Digital technologies | Affordances of digital technologies | Technology can be used to deliver information |

| Discourse analysis | *Element* | Digital technologies |
|---|---|---|
| | *Conditions of possibility* | If one meaning of being a 'teacher' is to deliver information, technology can now act as the teacher in this role. |
| | *Positioning* | Teacher as a different kind of expert, cannot fight new ways. Teacher decides it is not his role anymore to "deliver information" but to curate information. |
| | *Identity* | Teacher as curator of digital information |
| | *Identity within discourse* | 21st century teacher |

**Teacher interview example two:**

Phase two/week 5/term 2/teacher to researcher during class time:

> *I love the idea of personalising learning, but I look at these guys (indicates to the two groups sitting at tables along one side of the room) and I think, unless they're forced to do something…can you imagine? They would be able to pick something, but to drive themselves in this way of learning… They'd have to be quite independent, they'd have to have really good mentors. Because I could see some kids working for an entire term and getting nothing and then we'd get blowback from parents.*

| Thematic analysis | *Elements* | *Theme* | *Category* |
|---|---|---|---|
| | Curriculum | Framework curriculum | Teacher can offer learning choices<br>Flexibility in curriculum |
| | Assessment | High stakes assessment driving behaviour | Teacher accountability |

| Discourse analysis | *Element* | Curriculum and assessment |
|---|---|---|
| | *Conditions of possibility* | Modular NCEA assessment and framework curriculum enable choice and open inquiry. |
| | *Positioning* | Teacher is concerned with student achievement in NCEA. Teacher wants to offer choices in learning, however, the teacher's duty to parents to ensure students achieve in NCEA results in an obligation to "force" students to "do something". |
| | *Identity* | Teacher as a taskmaster or teacher as learning guide and mentor? |
| | *Identity within discourse* | Tension between 21st century teacher and traditional achievement |

**Document example:**

Phase one/school 2/participant observation/Level one NCEA achievement standard

*AS90944* ***Science 1.5:*** *Demonstrate understanding of aspects of acids and bases*

*4 credits External*

*At Achieved level: Demonstrate understanding typically involves describing, identifying, naming, drawing, or giving an account of aspects of acids and bases. This may require the use of chemistry vocabulary, symbols and conventions (including names and formulae), and completing word equations.*

| Thematic analysis | *Elements* | *Theme* | *Category* |
|---|---|---|---|
| | Assessment | External achievement standards | Knowledge specified within level one acids and bases standard |

| Discourse analysis | *Elements* | Assessment |
|---|---|---|
| | *Conditions of possibility* | Modular NCEA assessment enables choice. Students can choose to enter external assessments. |
| | *Positioning* | In the examination students must demonstrate understanding of science knowledge/conceptual learning. |
| | *Identity* | Student as receiver and performer of specific conceptual knowledge |
| | *Identity within discourse* | Traditional learner |

**Observation example:**

Phase one/School 1/participant observation

*TT1 is standing at a whiteboard at one end of the commons space, talking to a large group of students who are mostly (but not all) seated in that same area. These students are entering* *the level one biology external achievement standard and are preparing for this examination.*

*TT1 to group: Genotype and phenotype – you're gonna have to know the difference between the two. Repeat it to me:* ***ph****enotype –* ***ph****ysical characteristic (TT1 puts emphasis on the 'ph' syllable in both words. Students then repeat this aloud with the teacher).*

| Thematic analysis | *Elements* | *Theme* | *Category* |
|---|---|---|---|
| | Assessment | External achievement standards | Knowledge specified within level one genetics standard |

| Discourse analysis | *Elements* | Curriculum and assessment |
|---|---|---|
| | *Conditions of possibility* | Modular NCEA assessment enables choice. Students can choose to enter external assessments. |
| | *Positioning* | In the examination students must demonstrate understanding of science knowledge/conceptual learning. Teacher has a duty to tell students what they need to know and ensure that they know it. |
| | *Identity* | Teacher as expert-knower and as sage on the stage. Teacher as knowledge coach. Student as receiver and performer of specific conceptual knowledge. |
| | *Identity within discourse* | Traditional teacher and learner |

## *Appendix I: Phase two Principal information and consent letter*

…. November 2016

Dear [Name]

As you know, earlier this year during Phase one of my PhD research into science teaching and assessment in ILSs, I spent one week observing and interviewing in [teacher name/s']'s science class.

Phase two is a collaborative action research project involving the trialling of teaching and assessment innovations within the existing framework of NCEA science achievement standards. I have been in discussion with [name/s], and we see one possibility is [discussion of issue/opportunity]. Together we hope to [brief explanation of 2 cycles of teaching and assessment trial/s and what it involves] in [name/s']'s 2017 level one science class.

It is hoped the research will make a contribution to teaching and learning in an ILS as we work to identify and exploit the potential of the NCEA assessment system alongside principles of 21st century learning such as [principles we are focusing on, for example, student-centred, inquiry learning]. It is hoped the research might contribute to professional development of teachers as part of reporting findings to the science learning community.

I am seeking permission to work with [name/s] to conduct this research.

With your permission the research would take place between [planned dates for teaching and assessing the 2 selected Achievement Standards] and would involve:

- Observation and audio/video recording in the science class and recording of field notes
- Students being informally interviewed by the researcher about their learning 'in the moment', during class time (brief, audio-recorded, conversational interactions no more than 2-3 minutes each)
- Students taking part in brief focus group interviews, following class or scheduled so as not to interrupt teaching and learning
- Researcher working closely with [name] as the trial is conducted, including informal unstructured interview and spontaneous, ongoing discussion

Collection of student work samples (all identifying factors will be removed and permission sought from the student)

The research project has been approved by the University of Waikato's Faculty of Education Ethics Committee and will be conducted under the supervision of Professor Bronwen Cowie from University of Waikato Faculty of Education. Fully informed consent would be sought from all participants before commencement of research.

[Name of teacher/s] have the right to withdraw from the research at any stage. Summaries of transcripts and observation notes will be provided to [name of teacher/s] for review on a weekly basis, and each week permission to use the data collected for research purposes will be sought. Once they have confirmed that their data and any associated analysis/interpretation may be used, it will no longer be possible to withdraw that data. Individual consent will be sought from each student and consent will also be sought from parents/guardians/whānau for students under 16 years of age. Students have the right to decline to participate in the research or to withdraw from the research at any stage.

The primary function of the research is for use in a thesis for a PhD degree at the University of Waikato. It is also possible that the findings of the research may provide the basis for academic journal articles, educational seminars, oral presentations and conferences at the outset of the research project. Given the small number of schools with ILS your school and the teacher's anonymity cannot be guaranteed. However, confidentiality will be maintained and no person will be named or talked about in any way outside of the research or in the thesis or subsequent publications/presentations. I will be careful in what contextual information I include.

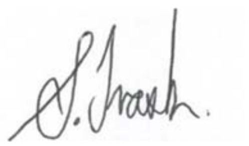
I am very happy to provide you with a short report on useful findings of this research and to share these with staff at your school. I will also provide you with an electronic copy of the final thesis once it has been completed, should you request this on the consent form.

Should issues or concerns arise during the project please feel free to contact me. If there is a question or matter you do not wish to raise with me, my supervisor, Professor Bronwen Cowie will be available by phone or email at the contact details below.

If you have any further questions, please contact me using the contact details below. I look forward to your response.

Thank you for your time,

Yours sincerely,



Suzanne Trask

Research Project: Principal: Permission to conduct research for Phase two

| | |
|---|---|
| **Research title:** | Repositioning students and teachers for science assessment in 21$^{st}$ century learning environments. |
| **Researcher:** | Suzanne Trask. Doctoral student, University of Waikato. |

- I give permission for the research as outlined in the introductory letter to be conducted in [Name] High School/College.
- I agree the information gathered in this study may be used for future research, publications, and/or presentations, and that under no circumstances will names, identities or any personal details be shared with anyone else.
- I would like an electronic copy of the thesis, once it is completed. YES/NO

| | | |
|---|---|---|
| Principal | Date | Signature |
| Researcher | Date | Signature |

## *Appendix J: Phase two Science Curriculum Leader information and consent letter*

…. November 2016

Dear [Name]

As you know, earlier this year during Phase one of my PhD research into science assessment in ILSs, I spent one week observing and interviewing in your science class. During this time we began discussing learning and assessment in ILS. We have discussed [the trial/intervention] as a possibility for a collaborative action research project which would inform Phase two of my PhD research. This letter seeks your free and fully informed consent to participate in the Phase two action research aspect of my study.

Should you agree to participate, the research would commence in 2017 during [teaching and learning of selected Achievement Standard/s] and would involve:

- Observation and audio/video recording in the science class and recording of field notes
- Myself as researcher working closely with you as action research partner as the trial is planned, implemented, refined and evaluated
- Students being informally interviewed by the researcher about their learning 'in the moment', during class time (brief, audio-recorded, conversational interactions no more than 2-3 minutes each)
- Brief focus group interviews with students, following class or scheduled so as not to interrupt teaching and learning
- Collection of student work samples (all identifying factors will be removed and permission sought from the student)

The research project has been approved by the University of Waikato's Faculty of Education Ethics Committee and will be conducted under the supervision of Professor Bronwen Cowie from the University of Waikato, Faculty of Education. Fully informed consent would be sought from all participants before commencement of research.

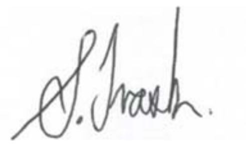
The primary function of the research is for use in a thesis for a PhD degree at the University of Waikato. It is also possible that the findings of the research may provide the basis for academic journal articles, educational seminars, oral presentations and conferences at the outset of the research project. Given the small number of schools with ILS your school and your anonymity cannot be guaranteed. However, confidentiality will be maintained and no person will be named or talked about in any way outside of the research or in the thesis or subsequent publications/presentations. I will be careful in what contextual information I include.

If you agree to take part in the study you have the right to withdraw your participation without providing a reason at any stage. To withdraw from the project, you will simply need to notify me verbally or in writing. You can also decline to answer any questions and or have data collected on you at any particular time. Summaries of transcripts and observation notes will be available on a weekly basis for review. Each week I will seek your permission to use the information collected. Once you have confirmed that the data and any associated analysis/interpretation may be used, it will no longer be possible to withdraw that data.

Should issues or concerns arise during the project please feel free to contact me. If there is a question or matter you do not wish to raise with me, my supervisor, Professor Bronwen Cowie will be available by phone or email at the contact details below.

I look forward to discussing the project further with you and look forward to your response.

Yours sincerely,



Suzanne Trask

Research Project: Phase two: Permission to conduct research for teacher

| | |
|---|---|
| **Research title:** | Repositioning students and teachers for science assessment in 21st century learning environments. |
| **Researcher:** | Suzanne Trask. Doctoral student, University of Waikato. |

- I agree to take part in the collaborative action research project, as outlined in the introductory letter.
- I understand that my participation is voluntary, and that I may withdraw at any time if I am uncomfortable with something I said being recorded.
- I agree the information gathered in this study may be used for future research, publications, and/or presentations, and that under no circumstances will names, identities or any personal details be shared with anyone else.
- I understand that if I have any concerns about the I can talk to the researcher, or if I prefer, I can contact Professor Bronwen Cowie (contact details are below).
- I would like an electronic copy of the thesis, once it is completed. YES/NO

| | | |
|---|---|---|
| Teacher | Date | Signature |
| Researcher | Date | Signature |

### *Appendix K: Phase two student information and consent letter*

…. March 2017

Dear students of [name of science class]

My name is Suzanne Trask. I am a full time PhD student at University of Waikato and am also an experienced science teacher. In my PhD research I am interested in finding out about teaching, learning, and assessment in science in a modern learning environment (or innovative learning spaces). This letter is to invite you to take part in my research.

[Title and name of Principal] and [title and name of science teacher] have agreed to allow me to do this research. I will be working with [teacher name] and with your science class to teach and assess [name of Achievement Standard/s] in a new way. We will be [brief description of how the Standard will be taught/assessed]. This will in no way disadvantage you in your final results and it is hoped the research will provide ideas for new possibilities and directions for future NCEA science assessments that can be used with other students.

During the research, with your permission, I would like to talk to you about your work – just brief three-minute chats - and to audio-record your responses. As well I would like to use a video camera to record the learning in your class. I may ask you to join a small group of students and talk to me after class about your learning. This would take place at a time and place that suited you and the group. I may ask to look at and take a photograph of some of your work.

It is important you know that I will be in your class as a researcher not a teacher. I will not be judging you or your work in any way. My goal is to hear your thoughts about being a learner in an innovative learning space.

It is important to understand you do not have to participate in this study. If you decline to participate this means that I will not talk with your or gather samples of your work. Even if you agree to participate in my research you can tell me not to collect data on you on a particular day/ time. For example, if I ask you a question you do not have to answer it. If I ask to see your work, you do not have to show me.

You will not be personally identified in the study, neither will your school nor any person at the school. Anything you discuss with me will remain confidential.

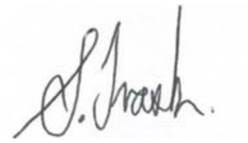
The information I gain from this study will be used in my PhD project and may also be used in an article in an academic journal or in a presentation. I will not identify you or your school in any way in any of these.

If I decide to use any photographs in which you can be identified in my thesis or papers I will seek your consent to use the specific photo.

If you agree to participate in the study please complete the consent form attached and give it to your teacher. If you have any questions that you think I have not answered you can ask me or my supervisor, Bronwen Cowie. We can be contacted using the details below.

I look forward to your response.

Yours sincerely,



Suzanne Trask

Research Project: Phase two: Student Consent Form

You are making a decision whether or not to participate in the research project as outlined in the invitation letter. Your signature indicates that you have decided to participate in the research project.

| | |
|---|---|
| **Title:** | Repositioning students and teachers for science assessment in 21st century learning environments. |
| **Researcher:** | Suzanne Trask. Doctoral student, University of Waikato. |

- I confirm that I have read and understood the invitation letter for the research project above and have had the opportunity to ask questions.
- I agree to take part in the research project as outlined in the invitation letter.
- I understand that my participation is voluntary, and that I may withdraw at any time if I am uncomfortable with something I said being recorded.
- I agree the information gathered in this study may be used for future research, publications, and/or presentations, and that under no circumstances will names, identities or any personal details be shared with anyone else.
- I understand that if I have any concerns about the research I should talk to my teacher or I can contact the researcher, or if I prefer, I can contact Professor Bronwen Cowie (contact details are below).

| | | |
|---|---|---|
| Student | Date | Signature |
| Researcher | Date | Signature |

## *Appendix L: Parent information and consent letter*

…. March 2017

Dear [Name]

My name is Suzanne Trask. I am a full time doctoral student at University of Waikato.

I am interested in finding out about teaching, learning, and assessment in science in a modern learning environment (or innovative learning space (ILS)). As part of my research I will be working with [title and teacher/s name] to teach and assess [name of Achievement Standard/s] in a new way. We will be [brief description of how the Standard will be taught/assessed]. This will in no way disadvantage your son/daughter in their final results and it is hoped the research will be helpful when carrying out future NCEA science assessments.

The research would begin in [month] and with your permission would involve:

- Observation and audio/video recording in the science class and recording of notes
- Students being interviewed by the researcher about their learning, during class time (no more than 2-3 minutes each) or interviewed in groups briefly after class
- Collection of student work samples (all names will be removed and permission will first be asked of the student)

The research project has been approved by the University of Waikato's Faculty of Education Ethics Committee and will be under the supervision of Professor Bronwen Cowie from the University of Waikato, Faculty of Education. Your son/daughter has the right to refuse to answer any particular question or to refuse to participate in the study at all.

The research is for use in a thesis for a PhD degree at the University of Waikato. It is also possible that the findings of the research may form part of a publication in an academic journal or may be used in a presentation. Confidentiality will be maintained and no person will be named or talked about in any way outside of the research. Neither will any person will be named in any way in the thesis or other publication/presentation.

Should you have any questions or concerns about the research, please contact either myself or Bronwen Cowie, using the contact details below. I look forward to your response.

Yours sincerely,

S. Trask

Suzanne Trask

Research Project: Phase two: Permission to conduct research:

Parents/whanau/guardians

| | |
|---|---|
| **Research title:** | Repositioning students and teachers for science assessment in 21st century learning environments. |
| **Researcher:** | Suzanne Trask. Doctoral student, University of Waikato. |

- I have read and understood the invitation letter for the research project above and have had the opportunity to ask questions.
- I/we agree to my son/daughter taking part in the research project as outlined in the invitation letter.
- I understand that participation is voluntary, and that my son/daughter may withdraw at any time.
- I agree the information gathered in this study may be used for future research, publications, and/or presentations, and that under no circumstances will names, identities or any personal details be shared with anyone else.
- I understand that if I have any concerns about the research I can talk to my son/daughter's teacher or I can contact the researcher. If I prefer, I can contact Professor Bronwen Cowie (contact details are below).

| | | |
|---|---|---|
| Parents/Whanau/Guardians | Date | Signature |
| Researcher | Date | Signature |

***Appendix M: Summary of identities associated with senior secondary science teachers and learners in the discourse of 21$^{st}$ century learning***

| *Element and learning choices supported* | *Possibilities for teacher identities* | *Possibilities for student identities* |
|---|---|---|
| *Curriculum:*<br><br>What, why and how to learn | **Expert-knower:** knowledgeable about scientific concepts, processes and capabilities, and knowledgeable of front end/Nos strand.<br><br>**Expert-learner:** current and updated specialist and general science knowledge; comfortable with not-knowing<br><br>**Expert-enabler of group and individual learning:** facilitator of learning framed by NZC. Select/interpret aspects of curriculum and assist students to ask questions from new/existing knowledge. Teach new knowledge as foundational/generative concepts and understandings where required. Assist students to be learners and inquirers. Orchestrate many individual pathways and performances of learning. May include taskmaster position to set the pace/direction for learning | **Choice-maker:** emerging knowledge of individual strengths, needs, and interests. Able to decide what/where/when/how/with whom to learn<br><br>**Learning leader:** independent yet in community, self-managed and self-directed learner<br><br>**Knowledge-builder:** has own science knowledge and able to extend, expand upon and communicate science knowledge<br><br>**Investigator:** asks and enquires into own curious questions in science contexts |
| *Assessment:*<br><br>What, why and how to learn | **Expert-knower:** knowledgeable about NCEA assessment processes. Knowledgeable of formative/summative assessment of NZC front end skills and capabilities<br><br>**Expert-enabler:** facilitator or enabler of students' demonstration of evidence of learning under NCEA. Assist students to be assessors of own application to work/progress | **Achiever in NCEA**<br><br>**Choice-maker**<br><br>**Investigator**<br><br>**Performer of knowledge:** must be knowledgeable about science and show that they know specific science knowledge in external examinations and internal investigative assessments |

| *Element and learning choices supported* | *Possibilities for teacher identities* | *Possibilities for student identities* |
|---|---|---|
| *Flexible learning spaces:*<br>What, why, how, where and with whom to learn | **Expert-enabler:** finds new ways to teach and deliver new knowledge where transmission is less feasible or effective. Acts as resource hub to connect students with other community resources<br>**Collaborator and team teacher:** interacts with other science specialists as in-school learning and assessment resources. Team teacher who provides learning choices for students | **Choice-maker**<br>**Learning leader** |
| *Digital technologies:*<br>What, why, how, where, with whom, and when to learn | **Expert enabler as digital pedagogue:** uses the affordances of digital technologies to assist students to learn<br>**Curator of online and community resources and knowledge:** survey, select, manage and oversee student access to appropriate material | **Digital learners:** able to exploit affordances of digital technologies as learning tools<br>**Choice-maker**<br>**Learning leader**<br>**Knowledge-builder** |