Futures Thinking in the Future of Science Education

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Introduction

In a world of unprecedented scientific and technological advancement there is increasing need for students to become equipped and empowered to contribute meaningfully to change, both in their places of work and in their social and political world. One aspect of this need is an ability to identify preferred future scenarios from a range of possibilities, and to then work towards these. Such decision making—about possible and preferred futures—forms part of what is variously called the futures field, futures studies, futures research, futuristics, prospective studies, or prognostics (Bell 1996) and has its origins in the strategic planning of governments and large corporations. Here, we use the term 'futures thinking' and consider its potential place in science education.

Futures thinking is beginning to find a place in school and tertiary curricula as 'futures education'. For example, New Zealand schools are required to include a future focus as a foundational principle in curriculum design and implementation (Ministry of Education 2007). This principle is about "supporting learners to recognise that they have a stake in the future, and a role and responsibility as citizens to take action to help shape that future" (New Zealand Curriculum Update 2011) and it is intended to permeate curriculum design decisions. Within science curricula, too, there is often implicit reference to future scenarios. For example, the national curriculum in England proposed for 2014 includes as an aim for science education that students are to be equipped with the scientific knowledge required to understand the uses and implications of science, today and for the future

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(Department for Education 2013). In the United States, one of the science benchmarks for Grades 9–12 reads: "Scientists can bring information, insights and analytical skills to bear on matters of public concern. Acting in their areas of expertise, scientists can help people *understand the likely causes of events and estimate their possible effects*" (AAAS 2009, emphasis added).

Futures thinking has strong natural associations with science education in that many current and future global issues have scientific and/or technological underpinnings. As such, futures thinking in science aligns closely with the exploration of socioscientific issues, or SSIs (Zeidler et al. 2005). Indeed, it is the futures focus of SSIs that many students find most alluring (Osborne and Collins 2000). However, futures aspects appear to be largely implicit in many SSI programmes, and we advocate for a much more overt inclusion in order to specifically develop students' futures thinking skills. In other words, while we applaud the intent of SSI programmes to develop students' moral reasoning, we believe that there is also potential for such programmes to develop students' futures thinking—but that, to date, little systematic work has been undertaken in this area.

As well as the natural association between futures and SSIs, futures thinking is also particularly relevant to science education since science (and technology) often form part of students' images of the future (e.g., Otrel-Cass et al. 2009). In addition, futures thinking is highly contextualised in that scenarios are developed from a range of stated parameters. This means that developing the futures thinking skills of students fits well with a context-based approach to school science. However, the field of futures thinking in science education is still pre-emergent in that there is very little research evidence of appropriate pedagogies, or the impacts on students' conceptual and affective learning.

This chapter considers one major aspect of the field of futures thinking in science education: the potential for futures thinking to engage reluctant learners in thinking about science. Here, 'thinking about science' includes thinking about the social, cultural and political milieu to which science contributes, and the relationship between science and technology. The context for the study was a programme involving one class of Year 9 (13 year-old) students of lower mixed ability. The research builds on earlier work using the framework for futures thinking developed by Jones et al. (2012). This framework includes five components—understanding the current situation, analysing relevant trends, identifying drivers, exploring possible and probable futures, and selecting preferable futures. In order to ground students' discourse in possible futures in science teaching and learning, a sixth component—underpinning science—was introduced.

Futures Thinking in Science Education

While 'futures studies' relates to the academic field of inquiry into possible futures in a broad range of contexts, 'futures education' refers to the translation of futures concepts into learning experiences that are appropriate for school students (Hicks

2012). The plurality of the name—futures—is deliberate, highlighting the range of possible futures and notions of alternatives (Slaughter 1996).

Futures thinking—which underpins both futures studies and futures education—assumes that the future world will differ from the present world; that the future is not fixed, but consists of a variety of options; that people are responsible for choosing between these options; and that small changes can become major changes over time. Most futures work incorporates considerations of the following factors:

- input data (observations, raw data, and empirical evidence that are analysed and synthesised to produce trends),
- trends (trajectories, extrapolations, projections, and predictions, based on an analysis of the input data; trends tend to be continuous and monotonic, i.e., relating to one aspect only, such as the increasing proportion of the world's population living in developing countries),
- drivers (groups of trends that share a common theme, e.g., demographics, globalization, economics, science and technology, equity issues, and environmental change),
- wild cards (high-impact, low-probability events, e.g., natural disasters), and
- outcomes (possibilities and scenarios) (DERA 2001).

The cumulative effect of even small uncertainties in any of these factors means that the range of plausible future worlds is very large.

Although the potential for explicitly including futures thinking in science education has not yet been extensively studied, some initial investigations have been carried out by David Lloyd and colleagues (e.g., Lloyd 2011; Lloyd et al. 2010; Lloyd and Wallace 2004; Paige et al. 2008). In addition, a small number of classroom resources exist, often with an environmental focus (e.g., Fisher and Hicks 1985; Hicks 1994; Slaughter 1995; UNESCO 2002). Extending some of these ideas, Jones et al. (2012) developed a conceptual framework to develop students' future thinking skills. Within this framework, students' attention is focused on identifying and analysing the existing situation, trends and drivers. Student understandings of these are then used to explore possible and probable futures in a structured format that reduces guesswork while still encouraging creativity. A consideration of the social context within which the changes might occur can take place at a personal, local, national, and global level. The intention is that recognising this range of levels will help move students' decision-making from an ego-centric activity to one valuing the welfare of the planet and all its occupants. Futures thinking should, therefore, provide opportunities—through the building of possible, probable and preferable future scenarios—for students to reflect on their own as well as others' values. Taking into account multiple perspectives and world-views is important for exposing students to some of the complexities and ambiguities associated with SSIs.

The potential benefits of developing students' future thinking skills therefore include fostering their creative, analytical and critical thinking skills; developing their futures vocabulary (e.g., past, present, future, the extended present, alternatives and choices, sustainability, future generations) as well as their values discourse—all critical for inculcating the foundations of a futures perspective (Slaughter 1995). Ultimately, futures thinking has transformative potential through empowering individuals and communities to envisage, value, and work towards alternative futures (Carter and Smith 2003; Delors 1998; Hicks 2003; Rawnsley 2000).

When students' images of futures are explored and valued, they can be a powerful vehicle for learning (Lloyd and Wallace 2004). There is, therefore, potential for futures thinking to engage students in science learning, and to increase their perceptions of the relevance of their science learning. There is also the potential for futures thinking to help students develop their understanding of key scientific concepts, including those related to the nature of science, and to evaluate the positive and negative potential impacts of science and technology on society (e.g., Carter and Smith 2003; Paige et al. 2008). The focus of the study presented in this chapter was on the first of the above outcomes—the influence of futures thinking on student motivation in science.

Futures Thinking to Engage Reluctant Learners

While our earlier work has investigated the usefulness of the futures thinking framework with academically able students committed to their education (Jones et al. 2012), we were also interested in its value for engaging reluctant learners in thinking about science. Such students pose significant challenges for science teachers, and there is considerable global concern about how to increase their engagement and achievement in science.

This chapter describes a small classroom-based case study where futures thinking was introduced to junior secondary science students. The class was a Year 9 class (13 year-olds), the first year of secondary schooling in New Zealand. It was culturally diverse—of 20 students, half were New Zealand European, almost a third Maori, and the remainder East Asian. The class size had deliberately been kept small by the school in an effort to make classroom management easier, and, as is common in this context, class attendance was very erratic. During the six futures lessons, only five of the twenty students attended all lessons, and four of the students were stood down from school during this time for three different thieving incidents. The class was described by the school as 'lower mixed ability', and only four students out of 17 passed (i.e., achieved a grade greater than 50 %) an end of topic test just prior to the futures lessons (three students had been absent for the test). There was significant disengagement in science learning, with many students choosing to not participate in class activities.

Since the 'success' of the futures thinking lessons was going to depend, in part, on the teacher's content knowledge and pedagogical content knowledge (Magnusson et al. 1999), the class was taught by Cathy (the first author). This strategy circumvented the need to 'upskill' the science teacher. While such teacher development will be a valuable future pursuit, it first requires evidence of the merits of including futures thinking in science—and there remains a dearth of such evidence given the pre-emergent state of futures education in science. Cathy is a familiar personality in the school, and she attended seven science lessons prior to teaching the futures lessons in order to develop rapport with the students and get to know their interests and classroom habits and behaviours.

Methodology

In order to investigate whether futures thinking could be used to engage the students described above—disengaged junior secondary learners enduring rather than enjoying science, and school in general—the class participated in a series of six lessons. An interpretive case study approach was adopted, described by Bassey (1999) as "enquiries into educational programmes, systems, projects or events to determine their worthwhileness, as judged by analysis by researchers, and to convey this to interested audiences" (p. 58). Accordingly, data were collected to enable the research team (the two authors) to "(a) explore significant features of the case, (b) create plausible interpretations of what is found, (c) construct a worthwhile story, and (d) convey convincingly to an audience the argument or story" (p. 58).

Because of the tight scheduling of the year's science programme, the futures lessons were taught during classes that were normally timetabled for students to be in English—but they were reminded each time that they were in the class to learn 'science'. All lessons were audio-recorded so that interactions between the teacher and students could be analysed, and students' written work was collected at the end of each lesson and photocopied. The English teacher, Mandi (a pseudonym), took great interest in the project and chose to observe all six lessons. This offered the research team an informed outsider's reflections on the lessons and how students had responded.

The Futures Lessons

The six futures lessons are described below alongside some of the students' responses as a window into how the futures thinking framework played out with this particular group of normally reluctant junior secondary learners. Readers' attention is drawn to the variety of focal artefacts used to initiate and facilitate learning conversations, and the malleability of the futures thinking framework to be customised depending on the purpose of the teaching programme—in this case, to engage the learners in thinking about science and its role in everyday life.

Introducing Images of the Future

In order to introduce futures thinking and ground the lessons in contexts with which students were familiar, the first lesson consisted of two parts. First, a series of examples of past predictions were displayed and discussed, for example, delivering airmail using parachutes (predicted in 1921) and a surprisingly accurate prediction from 1900—a vision for Skype. The focus of the discussion, led by Cathy, was on how difficult it can be to predict the future, but that often science or technology is involved. In the second part of the lesson, students were shown photographs from three movies set in the future and asked what images of the future these movies evoked. Whole-class discussion focused on potential impacts on society as well as identifying some of the science that might be involved. In other words, both science and the potential social impacts were explored. For example, the movie 'Total Recall' predicts a highly automated society living and working in extremely tall buildings with little access to nature. This stimulus was used as the basis for discussing materials development and power generation (to enable such tall buildings to be built and supported), where and how food might be produced, and the potential impacts on people when they are disconnected from nature.

Next, students worked in small groups to choose a movie with a future theme and identify three predictions about the future that it portrays. The students were able to access computers for this task, and many of them watched movie trailers. In the second lesson, students reported back on the movies they had chosen and images of the future portrayed in the movie. Movies that were identified by students included: 'Looper' (set in 2074, includes time travel), 'Iron Man 2' (time unknown, includes powered armour), 'Total Recall' (set in 2084, involves memory replacement), Avatar (set in 2154, involves interplanetary travel and avatars genetically matched to their human operators), and 'Oblivion' (set in 2077, involves inter-planetary travel).

Mandi, the English teacher, highlighted the value of this approach for developing students' critical literacy. She commented after the lesson:

> The movies are great. It's what these students are most likely to connect with. They're not going to be reading or thinking about articles questioning future issues and challenges, or what the impacts might be on society. They don't watch movies critically either, but if there's going to be a forum that starts to get them thinking about things that are going to have an impact on their lives, it's going to be movies. And if you start the process now of thinking critically about what is being revealed, hopefully some of it will embed, stick.

Through facilitating the discussion, Cathy was able to keep steering the focus of the discussions to possible features of the future world, science understandings that might be needed, and social implications. She also deliberately created opportunities for all students to participate in the discussion in an effort to retain their engagement and focus.

Identifying Trends, Drivers and Relevant Science Knowledge

During the second half of lesson 2, Cathy led a whole-class discussion on past, present and possible future cell phones in order to introduce students to 'trends' and 'drivers' as concepts. Cathy created a bridge into this part of the lesson by pointing out that while it can be difficult to predict the future, we can develop possible scenarios by examining the present situation and changes that might shape future developments. In order to stimulate discussion about trends in cell phone development, an advertisement from the 1980s (available on *YouTube*) was played. Similarly, *a YouTube* clip of a 'futuristic cell phone ad' was used to initiate discussion about possible future developments in the cell phone industry. Table 1 captures the notes that were written up on the board to record class discussion.

The third and fourth lessons were used to reinforce the concepts of trends, drivers and possible futures, once again using whole-class discussion focused around stories, images and movie clips to recap the earlier lessons as well as consider possibilities for future cars and foods. Cathy summarised student responses on the board, and they also had worksheets on which they could write their ideas. Heavy reliance on teacher-student dialogue was considered to be somewhat risky by Mandi, who indicated that the students were much more used to spending time copying notes from the board—and that this was seen as a mechanism for 'managing' student behaviour, particularly in classes considered to be 'disruptive' and 'reluctant':

> Students are so conditioned to value what is written down. Even if they complain about writing, they've been conditioned to believe that *that* information is valid and important. It's also often used to manage their behaviour. But I think that's one of the tragedies—we've totally undersold discursive learning, or learning by discussion.

Table 1 Cell phones: past, present, future

Past	Current	Changes (trends)	Reason for change (drivers)	Future possibilities	Science involved
Bulky, heavy	Thin, light	More portable	Market share—companies developing new ideas to sell more phones	Transparent materials—new materials	Signal transduction
Cords	Multi-functional—phones, apps, Internet, games, cameras	Cordless	Consumer demand	Holographic displays	Electronics
Telephones only (single function)	Wide range	Increased functionality	New technologies (LCD screens, touch screens, changing battery sizes)	On or in our bodies	Sensor technology (touch screens)
Expensive	LCD screens	Increased accessibilty			
		A fashion item			

Mandi was surprised by the sustained level of student engagement and participation in the class discussions, and their connection with the intended learning:

> They've been able to sustain a high level of thinking—higher than normal for them. What I was impressed with today [the fourth lesson] was that they've continued to be engaged with the process, and it hasn't seemed to wane. And they're making the connections. The way they were able to reflect on what was discussed in the previous lesson—there was the right balance of prompts to remind them, and they came up with the terminology—trends, drivers.

Importantly, by facilitating the class discussions, Cathy was able to maintain an emphasis on the scientific knowledge that might be needed to underpin future developments. In order to reinforce this, she used narratives to introduce science developments that had been necessary stepping stones in developing modern technologies. For example, LCD screens depend on the late 19th century discovery that cholesteryl benzoate has two melting points, and between these it has properties of both liquid and crystals. The purpose of this and similar narratives was not only to engage students in some of the stories of science but to emphasise the importance of scientific discoveries in many contemporary technological developments. Short explanatory movies about possible futures were also selected because of their references to the underpinning science. For example, a clip of the Google self-drive car was chosen because of its narration by Kathy Sykes, a British physicist and broadcaster, who describes some of the science-based features of the car, including a 64 laser scanner on the top of the car to measure the distance of surrounding objects.

The social context and implications were also discussed in all of the examples that were talked about, for example, the reliability of self-driving cars, the challenge of feeding a growing population. Again, this discussion needed to be mediated by the teacher, who throughout the lessons had the following clear goals in mind:

- to help students identify changes over time (trends) and what might be influencing them (drivers),
- to highlight the importance of science in possible future technological (and other?) developments, and
- to contextualise the future within a broader social framework.

Pulling it Together

In the fifth lesson, students were tasked with choosing a context in which they would explore: the past, the present, trends, drivers, possible future developments, and the underpinning science. In the following session they would share their ideas. As a class it was decided that at least three trends and drivers would need to be identified, two possibilities for the future, and two aspects of science that would be needed. The students, therefore, helped negotiate the assessment framework.

The students had access to computers and there was a mix of individuals and pairs or threesomes working together. Each individual or group had a worksheet with a table with headings as shown in Table 1. Key to the discussions was choosing a suitable context and then being able to effectively search the Internet for relevant material (ICT literacy). Cathy circulated around the class, interacting with all students about both of these issues, helping students to refine their topics, suggesting terms to use in Internet searches and then helping students filter the results to identify useful information. For example, Tammy and Leah (pseudonyms) wanted to explore future fashion. Cathy reminded them that they would need to think about links to science and suggested that they investigate how fabrics have changed, why there have been these changes, and what new materials might be developed in the future. However, she quickly realised that the limited background knowledge of the two girls would significantly impact their ability to make progress—they were almost immediately distracted by references on the Internet to ‘cellulose-based fibres’ and ‘synthetic fibres’ and did not have even a rudimentary understanding of different materials such as cottons, linens, polyesters and nylons. Because of this lack of understanding, Cathy suggested that they choose another topic. Here again, her guidance was critical in refining the context for investigation—from specific singers/bands that would become more popular (Tammy’s first idea), to ways in which music is accessed (‘changes in the music industry’ resulted in a particularly fruitful Internet search).

For students who very seldom experience lessons where they need to work independently of the teacher, with ready access to computers, there was a high level of on-task behaviour. Although some groups complained about the amount of reading that was required to identify information relevant to the task, with encouragement they persisted. Discussions among the student groups tended to be animated but focused, and several students found fascinating images of past and possible futures related to their topics. One boy also drew heavily on his funds of knowledge (Moll et al. 1992), leading his group’s discussion about future possibilities for televisions by drawing on his father’s experiences as manager of a large electronic appliance store and telling the others about some of the new televisions that were about to be introduced into the market. In contrast, a group of four boys were significantly disruptive and were repeatedly asked to focus on what they were doing. Closer examination suggested that these boys all had very low levels of literacy and ICT literacy, and searching the Internet was an extremely challenging task for them.

The presentations of student work in the subsequent lesson were deliberately low key so as not to force students to take on a role of ‘speech maker’ in front of the class, which many would have found intimidating. Although Tammy and Leah had prepared a PowerPoint presentation to which they spoke, the remaining students sat at their desks and read out their ideas and the teacher collated these on the board. This process facilitated the creation of a visual artefact that all students could access (Wenger 1998), and enabled important learning conversations between the student offering the idea, Cathy clarifying this idea, and other class members contributing refinements. It also meant that in cases where individuals or groups had developed the same context, ideas could be collated. In addition, Cathy could reinforce technical language, for example, 'market share' rather than 'sell more than other companies' and 'multi-functional' rather than 'decent phones' or 'has lots of apps and things'. While the majority of the class participated actively in the discussions, a small group of boys (all of whom had missed earlier lessons) were disengaged and disruptive throughout the lesson.[1] It was encouraging to notice, however, that one boy in their midst still chose to contribute his ideas despite overt pressure not to do so.

In total, five different future themes were developed: cell phones, cars (both with substantive additions to ideas previously discussed in class), televisions, future food, and the music industry. Of these five, the best developed was past, present and future ideas associated with televisions, as shown in Table 2.

At the end of the lesson, Mandi reflected on the students' contributions and behaviour:

> They've come a long way. Teresa, Lindsey, Lance [pseudonyms]—if you could see their behaviour in other contexts the difference would be extreme. And I think the level of thinking that was happening—that had probably been happening in the first lessons and then solidified in the computer lesson—I think that was very encouraging and hopeful. It's been a huge shift for them.

Her reflection on the culture shift that had begun to occur was more disturbing:

> Perhaps the tragedy of what's happened is that you've highlighted what's missing. They're only just going to really start unpacking why this is different, and what the potential is for their learning, and now they're going back to the way things normally are, where they actually have very little opportunity to really give their ideas.

This reflection is a salient reminder of the extensive research evidence supporting student-centred, interactive pedagogies—juxtaposed against a classroom culture in which teachers seek to 'manage' behaviour and 'cover' content by limiting opportunities for interaction and exploration.

Student Views

In order to gain insights into students' views of science prior to and after embarking on the futures lessons, a short questionnaire was administered at the beginning and end of the six lessons. From the beginning, students' views were positive about science, in spite of their high levels of disengagement in their school science

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[1]One of these students, a key player in the disruptions, was subsequently excluded (expelled) from the school for a series of illegal activities. His story is included here both to be true to the description of the classroom environment, and to highlight the leading role that some students play in influencing class culture. In spite of his insidious influence, including notorious bullying, many of his peers showed admirable determination to contribute meaningfully to the classroom interactions.

Table 2 Televisions: past, present, future

Past	Current	Changes (trends)	Reason for change (drivers)	Future possibilities	Science involved
Big boxes	Flat screens	Larger, thinner screens	Increase market share—people want to buy 'the latest'	3D and interactive experiences	LCD screens
Originally black and white and no sound	Multiple channels	Increased quality	Reducing cost	Voice- and movement-activated	Sensor technology
Limited channels	Surround sound	Increased choice	New technology	Multi-screen displays	Electronics—sending and downloading the digital signal
Pixellated	High definition	Analogue to digital			
Bunny ear aerials	UHF aerials	Multi-functionality			
Analogue	Digital	Greater user choice and control			
	Recording multiple channels				
	Remote controls				

lessons. For example, of the 16 students who completed the questionnaire before the futures lessons, all 16 agreed or strongly agreed with the statement *I like finding out about new ideas in science*. Nearly all (14 out of 16) agreed or strongly agreed with the statements *I think science can be interesting* and *Science is important for New Zealand's economy*. Fewer—11 out of 16—agreed or strongly agreed that *Science is important in my everyday life*. Given the positive perceptions prior to participating in the futures lessons, it is not surprising that no attitudinal gains were evident when the questionnaire was administered after the futures lessons, except that three students ranked *Science is important in my everyday life* more positively than they had done previously.

Similarly, students' responses to how much they had enjoyed the futures lessons did not reveal any clear trends: half the students indicated that they had enjoyed the lessons a lot (8 of the 16) and half had enjoyed them 'a little'. Similarly, half indicated that it was the topic that had been most important and the other half indicated that it was the teaching style. The teaching style was described as 'fun' and 'cool', with specific mention made of how the teacher had included all students in the class discussions (e.g., 'she talked to everyone') and summarised discussions on the board (e.g., 'I like the way she set it out on the board'). It is therefore difficult to disentangle the impact of 'futures thinking' as an area of learning, and the new pedagogical approach on students' engagement. However, it does seem that the nature of futures education in general, and the futures thinking framework in particular, lends itself for a more transactional pedagogy rather than a transmissive one.

Re-visiting the class five months later, Cathy asked the students what they remembered about the lessons they had done with her. She was impressed by the extent of their recall, particularly about some of the broad areas of science that had been discussed (solar panels, network connections, data management, signal recognition). Students were also able to participate in discussions about trends and drivers, giving examples. Perhaps most encouraging was that students recognised that the lessons had been 'science' lessons, despite having taken place during classes timetabled for English, with their English teacher present, and with considerable discussion about social implications. Interestingly, some students went on to talk about whether the lessons had been science or technology, and what the differences between these might be. This presents an area for fruitful future development with these students. It also indicates the value of using technological examples to engage students in science—an approach that has long been advocated in curricula and research (e.g., Fensham 1988; Jones and Kirk 1989).

Discussion and Conclusion

The study described above was designed to investigate whether the futures thinking framework could be used to engage a group of normally disengaged, reluctant 13-year-old learners in thinking about science. This was the students' first guided foray into the world of futures thinking and it was encouraging to see how many of the students not only engaged in the process, but did so enthusiastically. As such, this small case study offers insights into the potential value of structured exploration of possible futures for connecting students' science learning with contexts in which they are interested. As Lloyd and Wallace (2004) argue, futures thinking can be considered to be an integral part of students' worldviews, and their futures images constitute prior knowledge that can influence motivation, conceptual development and what is valued as knowledge. Although the focus had not been on developing students' conceptual understanding about specific science concepts, but rather to engage them in thinking *about* science, the lessons could potentially have been extended to engage students in further learning *of* science.

The pedagogical approach of transaction—where students' ideas were solicited and then woven into and used to direct whole-class discussion—was not one with which the students were accustomed, as evidenced in conversations with both the students and their English teacher. (In addition, earlier observations of the students' science lessons indicated that when students were asked questions, the teacher was usually seeking one 'correct' answer.) Student engagement was generally high throughout the lessons and some students specifically commented on how they had valued the way their ideas had been included. Taking students' ideas into account also meant that the learning conversations remained grounded in experiences with which students were familiar. For example, considerable time was spent discussing the resistance of future materials to 'tagging' (graffiti)—raised by one of the students in response to a scene in a movie clip of digital road signs—and this was used by Cathy to introduce discussion about materials science. In other words, the interactive, transactional pedagogy enabled classroom dialogue to form around the ideas that were contributed by students. However, the general direction of the conversation was controlled by Cathy. Key to her approach was her clarity with respect to the goals for the discussions—identifying trends, drivers, possible futures and the underpinning science.

Identifying the relevant science was a key goal because futures thinking had specifically been introduced as a way to engage students in thinking about science. Formative interactions were critical in supporting students to explore their thinking and develop their learning in this area. For example, Cathy needed to keep asking questions like 'What science do you need to know about in order to develop…?' While the students likely did not have deep understanding of what they were identifying as science (e.g., how cell phones detect and transmit electromagnetic radiation, or even what electromagnetic radiation is) the emphasis in this case study was on highlighting scientific knowledge as being important for many potential technologies. Further research is needed to investigate how these initial conversations can be leveraged to engage students in learning about specific scientific concepts. For example, Mandi, although situated in an English teaching tradition, was excited about the potential for contextualising science within a futures scenario:

> I can see how you could build a whole science course around futures thinking—use the futures thinking to introduce the science concepts and unpack these in more detail. And maybe even use this kind of course to create greater cross-curricular opportunities.

Unfortunately, while the students' usual science teacher had been curious about the research, his allegiance to a traditional science curriculum meant that he remained unconvinced about the place of futures thinking in a science classroom. Herein lies a significant challenge to the shifts that will be required if science education is to be relevant and worthwhile for students in the future.

While there was some discussion about the similarities and differences between science and technology in Cathy's later visit to the class, these two fields draw on different epistemological assumptions (Jones 2012). A useful extension of this study would be to investigate the impacts of explicitly exploring with students differences in the nature of science and the nature of technology using examples introduced in the futures thinking lessons. A narrative approach to introducing aspects of the nature of science appeared to be well received by the students. While any changes in their subsequent understanding of the nature of science were not evaluated, the interactions did highlight the potential for such narratives to introduce various aspects of the nature of science. For example, the story of the discovery of the liquid crystal phase by Friedrich Reinitzer, an Austrian botanist studying chlorophyll, was used to highlight the serendipitous nature of some scientific discoveries, the need for collaboration and corroboration (Reinitzer approached a physicist for help in confirming his finding), and that innovation often occurs at the intersection between the sciences and technology (a botanist discovered something that was eventually developed into a product by physicists and engineers). Of course, the discussion of these insights was only possible because of the Cathy's content knowledge with respect to both the details of the narrative and relevant aspects of the nature of science. In preparing for the futures lessons, however, she was cognisant of how easy it was to locate appropriate reference materials on the Internet that she could draw on in class.

Another avenue for deeper learning is the values dimension of futures education, which was not explored in this case study in that students were not required to identify and distinguish between possible, probable and preferred futures. However, the values dimension represents an important extension for student learning (see Matthews, this volume), and is offered as a key justification for including futures thinking in school (e.g., Hicks 2003). For example, it is values discourse and decision making that will enable students to become increasingly aware of their own and others' values, and the complexity of decision-making in contexts laden with social, political and economic nuances. This is consonant with Barnett's (2004) exploration of how students can be prepared for a complex world of interrelated systems. He concludes that learning for uncertainty, for what he calls an 'unknown world', cannot be accomplished by the acquisition of either knowledge or skills; the challenge for educators is to prepare learners to cope with, and thrive in, a situation of multiple interpretations. It must also be noted, however, that the multifaceted process of learning about various possible futures can challenge existing thinking and so be unsettling, emotionally as well as cognitively, for individuals (Rogers and Tough 1992, 1999).

What the study does show is the potential of the futures thinking framework to support a transactional pedagogy, and the ways in which it might be modified to suit different teaching contexts. In this case, the purpose was to engage reluctant learners in thinking about science, but there was significant potential to extend this learning to developing students' conceptual understanding of specific science concepts, and/or their values discourse in evaluating alternative possible futures. The incorporation of futures thinking in science education continues to be relatively un-researched, and we hope that the study presented here offers encouragement to science teachers and science education researchers to delve more deeply into identifying the possibilities that might exist. Indeed, as educators of the next generation of global citizens and leaders, it may be irresponsible to do otherwise.

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