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Use of Future Scenarios as a Pedagogical Approach for Science Teacher Education

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Abstract Futures studies is usually a transdisciplinary study and as such embraces the physical world of the sciences and system sciences and the subjective world of individuals and cultures, as well as the time dimension—past, present and futures. Science education, where student interests, opportunities and challenges often manifest themselves, can provide a suitable entry point for futures work. In this paper, we describe how we have used futures themes, concepts and techniques both implicitly and explicitly in our undergraduate middle school teacher education courses and, in particular, science curriculum and general studies courses. Taking a critical orientation to the past and the present in these courses enables the future to be more than a mere reproduction of the status quo and opens up a range of possible futures in the areas of current interest. For example, having studied middle school teaching and learning in mathematics and science, students explore the past, present and possible future of a natural part of a university campus. In a general studies course on the science of the Earth's atmosphere, students construct a normative futures scenario on living in a changing climate. One way to gain insight into an uncertain future is to construct scenarios. This technique has been used since the 1970s to bring issues of environment and development—areas with strong science content—to the attention of both scientists and policymakers.

Keywords Futures thinking · Future scenarios · Science teacher education

Introduction

In times of rapid change in local and global settings, it is essential to provide tools that enable people to explore possible and preferred futures that consider social and environmental justice. In this paper, we argue the value of futures thinking for education and, in particular, for science education. Drawing on research into the value of integrating a futures dimension into our undergraduate middle school teacher education courses, we demonstrate how a critical futures

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orientation in science education courses has enabled futures studies to be made explicit for pre-service educators. Students' futures scenarios, course evaluations and focus group discussions are the key data sources for this paper. We begin with a justification for futures thinking in science education. Next, we provide an outline of the research context, research methods and analysis of student-developed futures scenarios. We finish with insights into the value of including futures studies in science education.

Why Futures Thinking in Education and, in Particular, Science Education

In this section, we summarise arguments from the literature that futures thinking (foresight) is a natural disposition and therefore an important aspect of who we are as humans. We develop our argument around the following key themes: futures thinking as a natural disposition, history of futures studies and futures in education.

Futures Thinking as a Natural Disposition

Because we have memories of the past and can imagine possible futures, we have always been in a sense futurists. It is a fundamental attribute of humans that our memories of past experiences and our expectations of the future together enable each of us to live with meaning in the present. Imagining futures forces us to think about the basic questions of life (Masini 1993); that is, how we perceive the future—whether with hope or trepidation—matters to us and to society (Eckersley 1999, 2010, 2012). Many authors, including Boulding (1996), Francoeur (1976), Manuel and Manuel (1979), Russell (1982), Slaughter (1995a) and Tough (1995), identify historical evidence that shows the importance of images of possible futures. The Dutch social scientist Fred Polak (1973), who was the first writer to deal explicitly and in depth with images of futures from an historical perspective, realised the importance to a society or culture of having an ideal, dynamic image of the future. In his study, he showed that images of possible futures are central to the health of a civilisation and that there is a correlation between a society's general health and the nature of the dominant image of the future. He warned of the great dangers to Western culture should it lose its ability to generate powerful images of futures. Our ideas and stories are the blueprints for our future. Of course, ideas and stories do not arise in a vacuum. They come out of particular times and places (Eisler 2007). Our current particular time is one of rapid change, as far as can be judged, more rapid than any time in the Earth's history (Raskin et al. 2002).

One way to gain insight into an uncertain future is to construct scenarios. Constructing futures scenarios has been used since the 1970s to bring issues of environment and development—areas with strong science content—to the attention of both scientists and policymakers (Gallopin 2002). Futures visioning is Lowe's (2009) first step to a sustainable world: "Unless there is vision, there is no motivation to change. Without a vision, change might actually make things worse rather than better" (p. 99). Futures scenarios are his step to solving current issues—"to picture the future we want" (p. 99). This vision should be informed by more than the best evidence available, it "should also be informed by a sense of what ought to be" (Ogilvy 2002, p. 115). Eisler (2007) sees long-term planning as essential to "protect our increasingly fragile ecological systems" and argues that "we need to consider the long-term effects of new technological breakthroughs, and that our children and grandchildren will suffer greatly unless we think further ahead" (p. 150).

A Brief History of Futures

A possible starting point for contemporary futures studies is its foreshadowing by H. G. Wells, who in 1901 proposed 'a science of the future'. In a radio talk on the BBC in 1932, Wells said that in order to anticipate and prepare for the future, professors of foresight and entire faculties and departments of foresight were needed (Bell 1998; Slaughter 1989). Futures as a serious pursuit emerged after World War II as a result of new challenges in the military, the industrial world scene, in business and economic planning and technological forecasting (Cornish 1977) and emerged as an academic discipline in the 1960s (Bell 1996). Futures studies has continued to develop to this day as a field of endeavour that has its own epistemological commitments, concepts, methods and growing literature (Bell 2001; Slaughter 1996b, 2002). Futures studies in its current form is thus a relatively young area and has come into its own as a response to the rapid and unpredictable changes that are occurring globally (Bell 2007; Cornish 1977; Laszlo 2001; Raskin et al. 2002).

Futures study is a multidisciplinary and systematic field of inquiry of probable, possible and preferable futures. Inayatullah (1998) suggests that today it can be seen as being about understanding the human condition, what it has become and how we can participate in changing it. Milojevic (2005) summarises the key philosophical assumptions, gleaned from prominent futurists (Amara 1981; Bell 1997; Cornish 1977; De Jouvenel 1967; Masini 1993; Slaughter 1996a), as follows: the future is not predetermined and cannot be *known or predicted*; the future is determined partly by history, social structures and reality and partly by chance, innovation and human choice; there is a range of alternative futures which can be 'forecast'; future outcomes can be influenced by human choices; early intervention enables planning and design, whilst in 'crisis response' people can only try to adapt and/or react; ideas and images of the future shape our actions and decisions in the present; our visions of preferred futures are shaped by our values; and humanity does not make choices as a whole nor is it motivated by the same values, aspirations and projects. Such a framework is most helpful for science learning where we want to connect scientific understandings to socio-political situations as developed, for example, in Roth and Désautels (2002).

Whilst futures work is traditionally the province of futurists, it has become more common in recent times for scientists and other professionals to use this approach. For example, Robert Costanza (2000), Tim Flannery (2010), Murray Gell-Mann (1994), James Hansen (2009), Ervin Laszlo (2001), James Lovelock (2014), Ian Lowe (2005) and David Suzuki (1990) all use futures scenarios as a tool in their work as scientists and science communicators.

Our world is becoming increasingly interconnected and interdependent, which brings not only complex challenges but also new opportunities for collaboration in working towards common goals. It also requires a keen disposition for foresight. There are now science journals with 'futures' in their title—for example, *Future Virology* and *Future Microbiology*. Nunn (2007), principal scientist (Animal Biosecurity) at the Australian Government Department of Agriculture, Fisheries and Forestry, reports that foresight is something that has become important in science-related studies in order to work out what is facing us in the future. He provides a powerful example in the area of Australia's biosecurity: using foresight scanning, a well-established futures technique (Dator 1996; Slaughter 1987, 1995b), the worrying colony collapse disorder in bee hives, not yet present in Australia, was picked up in the literature and is now being studied. It is not only scientists who need to be scanning the future. Costanza (2000), a leading ecological economist, makes the point that

> The most critical task facing humanity today is the creation of a shared vision of a sustainable and desirable society, one that can provide permanent prosperity within the biophysical constraints of the real world in a way that is fair and equitable to all of humanity, to other species, and to future generations.

The creation of a shared vision of a normative future requires the contribution of many ways of knowing, including an understanding of how natural and social systems work, and a critical approach that considers eco social justice.

Futures in Education

Futures in education has become an established aspect of curriculum and pedagogy since the 1960s and in Australia was given high status by the Commission for the Future's Bicentennial Futures Education Project (Slaughter 1989). Futures in education is a translation of the futures field of the professional futurist to the classroom setting. Bell (in Hicks 2002) comments that "we desperately need a future oriented curriculum at all levels of education" (p. xvi) primarily because the educative process can be enhanced when teachers learn about the images students have of possible futures and use this source of student interests and concerns to build curriculum. Futures work in education helps students to "develop creative ideas and projects for a better society" (Hicks 2002, p. 56). The futures in education literature theorises futures pedagogical practices and describes ways of using futures concepts, capacities, perceptions, processes and methods in an educational context (Gidley and Inayatullah 2002; Hicks 2002; Hicks and Slaughter 1998). Slaughter (1989) argues that to take away the futures dimension "removes the 'space' needed for plans, purposes, goals, meaning, intentions and so on" and that without this futures dimension "what remains is not worth living in" (p. 14).

There is considerable evidence to suggest that what we think about the future affects all aspects of the self, including our state of well-being (Eckersley 2002; Frankl 1964; Goodall 2003; Hicks 2002; Hutchinson 1996). For example, the process of decision-making and current behaviour depends on the image that an individual or groups of individuals holds. An individual or group that "has no sense of direction in time, no sense of a clear future ahead, is likely to be vacillating, uncertain in behavior, and therefore to have a poor chance of surviving" (Boulding 1956, p. 7).

"Visions of a better world can guide social action and provide personal inspiration and hope" (Eckersley 2002, p. 39). They certainly provide a wealth of interesting ideas and possibilities for a range of studies across the curriculum that are of interest to students and often closely connect to the mandated curriculum. Hicks (2002) argues that it is not only important for educators to find out what students think about the future for curriculum planning and teaching purposes, but that students should be supported to create and develop preferable futures. We argue that futures should have a significant place is science education. Although there are many ways of using the tools of the futurist in education (Gidley and Inayatullah 2002, Hicks 2002, 2012; Hicks and Slaughter 1998; Hutchinson 1996), in our work, we have focused specifically on the use of futures scenarios. Futures scenarios elicit and communicate speculative thoughts and imaginative ideas about future developments. The writing of such scenarios requires the skills of the synthesis of data from a range of sources, and the generation of discussion, critique and shared understandings.

In much of present schooling, and particularly in science learning, students' images of possible futures are rarely if ever taken into account and, if they are, it is within the

context of a mechanistic worldview, popular culture and the mass media (Hicks 1998; Page 1996). We argue that students' images of the future are an aspect of their prior knowledge in science learning and a dimension of their well-being (Lloyd 2001, 2007a; Lloyd and Wallace 2004). There is a correlation between students' images of possible futures and self-esteem, between students' images of possible futures and social responsibility, and between students' images of possible futures and academic progress. Self-esteem, social responsibility and academic progress are all improved when students have optimistic expectations for the future (Eckersley 2002; Page 1996). Further, integrating a futures dimension into science learning can enable students to develop a more future-oriented perspective (foresight) towards their own lives and events in the wider world and to identify and envision alternative futures that are more socially and environmentally just and sustainable (Gidley 2002; Gough 1989; Hicks 1996; Holden 2002; Masini 1993).

For science educators who are interested in emphasising meaning as well as understanding, futures work is a valuable tool in the learning process (Tytler 2007; Roth and Désautels 2002). Many writers in the area of futures (Costanza 2003; Giri 2002; Tognettim 1999; Visvanathan 2002), and other fields of study such as Wilber's (1997, 1998, 2000) transpersonal philosophy" and postmodern science (Griffin 1988), argue for science to be more broadly based than the descriptive aspects of communities and their environment and to be actively interested in the guiding beliefs or ideals that characterise a community (world view), and the practice aspect (praxis), which represents manifestation and action (Sterling 2001) and has an explicit futures dimension.

Masini (1993) sees education as not always relating to the present or future needs of young people even though educators and others are aware that many students suffer from uncertainty, depression, frustration and fear concerning their personal and community futures (Eckersley 1988, 1999, 2002; Slaughter 1988). This observation is also identified by science educators. Tytler (2007), for example, writes that

> [w]hat we need to do is to shift the focus of school science away from the rehearsal of resolved concepts, towards science ideas being explored as powerful and flexible tools with which to explore and interpret phenomena, particularly in situations that are meaningful to students and that link with their social and imaginative lives. (p. 15)

Our incorporation of futures thinking and techniques in science learning is consistent with an approach that connects science learning to students' interests and concerns and to students' lives and their community. This approach is not just for understanding the world but also for taking action in the world (Hodson 2003; Jones et al. 2012; Saunders and Rennie 2013). Barton and Osborne (2002) say that science learning from this perspective "can be placed in a position (its proper position) as a tool for enacting societal change for the better" (p. 167). Fensham (2000) points out that "science in the public arena is inevitably involved with other knowledge" (p. 77), and recommends four social purposes for science learning: developing personal well-being, socio-economic well-being, democratic well-being and scientific wellbeing (Fensham 2003). A futures dimension is an essential element of all of these purposes. Fensham (2003) also sees this more holistic or integral approach to science curriculum as "interdisciplinary integration", and as a necessary approach to science learning "because most real world situations involving science are multi-disciplinary" (p. 8) and have an implicit futures dimension. A similar argument is made by those advocating a scientific literacy approach, in which students come to understand more about science and its processes, recognise its place in our culture and society, and are able to use it in their daily

lives (Darby-Hobbs 2012; Goodrum et al. 2001; Goodrum and Rennie 2007; Tytler 2007). For these reasons, in this paper, we evaluate the use of futures studies in science learning for pre-service teachers. We show how futures thinking has been central to science teacher education in the context of our primary/middle teacher preparation programme and in state and national curriculum frameworks.

Context: Science Teacher Education

This study was undertaken in the context of a primary/middle bachelor of education programme. A set of guiding principles was established by academics to provide coherence for the programme and to ensure that the pre-service teachers were well prepared to teach young adolescent learners (Lloyd 2004; Paige et al. 2008). One of the principles is futures thinking, which requires students to reflect on events and to develop the skills and foresight to manage and instigate change within educational settings. This approach is supported by the middle school literature (Groundwater-Smith et al. 2007; Venville et al. 2002) that also advocates connecting curriculum and pedagogy to students' life worlds (Gonzalez et al. 2005). The focus of our research is on the value of a futures perspective in science education.

Relevant Programme Structure and Links to Curriculum Documents

In preparation for the generalist primary component of the bachelor of education programme, pre-service teachers in the past 8 years have completed four curriculum courses in science and mathematics, three integrating science and mathematics and one focusing on numeracy. The integration allows all pre-service teachers to build their conceptual understanding as well as their confidence to plan science and mathematics learning experiences of increasing complexity, building up to pre-service teachers planning a transdisciplinary unit of work. It is in the fourth year that a transdisciplinary workshop sequence is modelled, part of which involves pre-service teachers constructing a futures scenario. Students can also select science general studies courses, including *Atmosphere and Climate* and *Astronomy and the Universe*. The numeracy and the two general study courses incorporate future scenarios as assessment tasks, and it is this material that provides the data for the research.

Futures has also been made explicit in curriculum documents in South Australia since 2002. One of the meta-organisers in the *South Australian Curriculum and Assessment Framework* (SACSA) (DECS 2002) was the essential learnings. The five essential learnings were futures thinking, interdependence, identity, thinking, and communication. This framework supported teachers to explore possible and preferred futures and to incorporate a futures perspective in science units of work. The nationally developed Australian Curriculum has now superseded the state-based curriculums and is less explicit in identifying futures as a theme for study (ACARA 2014). There are surprisingly few references to futures thinking in the science learning area, the general capabilities and cross curriculum perspectives. In science, the inclusion of implied futures is very narrow and technical, not reflecting the critical orientation required in this field. In our view, this will result in less uptake of futures thinking, a key twenty-first century skill.

Research Methodology

The research methodology we have used as participant-researchers is qualitative in nature and informed primarily by the work of Guba and Lincoln (1989). Because our research has been with classes that we teach, we have adopted an emic approach (sometimes referred to as 'insider,' 'inductive,' or 'bottom-up'), which takes as its starting point the perspectives and words of research participants. The constructivist approach values joint construction of meaning between the participants and the researcher, is directed towards local studies, has a sociopolitical orientation and is empowering for those who take part (Guba and Lincoln 1989, 2013; Lincoln 1990). These characteristics make the approach eminently suitable for our study with students. A constructivist approach accommodates the two roles of the teacher/researcher: the teacher 'as researcher' who has the responsibility for understanding their students, and teacher 'as educator' who has the responsibility of ensuring that valuable learning occurs. Within a classroom context, there is the opportunity for joint construction of meaning in a supportive, quality learning environment.

Research Questions

Future scenario course work described in this paper not only aimed to develop students' foresight skills but also assisted them in the integration of their learning by connecting it to their present lives and possible futures. It acts upon them now and in the future. The three key questions that underpin the study are as follows: 'In what ways did the writing of the futures scenarios support and enrich their learning?', 'In what ways do students say the futures work has changed their behaviour/values?' and 'Are futures scenarios effective as a pedagogical practice in science education?'.

Ethical Considerations

This study met the requirements of the guidelines for evaluation activities involving university staff and students. The evaluation responses were provided voluntarily, the anonymity of the respondents was maintained, pseudonyms have been used and the respondents were advised of the possibility that the data could be used for external publications. To avoid any conflict of interest as teacher/researchers, focus group discussions and analysis of the scenarios occurred after submission of grades.

Research Methods

We used a range of methods (Table 1): firstly, assessments of students' scenarios using the assignment criteria (SA) and secondly, from a voluntarily-completed, online course evaluation instrument (CE) (completed by just under 50 % of students). This provided data on both student satisfaction and the quality of the courses from a student perspective. Thirdly, we analysed student reflective writing undertaken at the end of the courses (SR). In addition, we have drawn on focus group discussion (FG) and round tables (RT) undertaken at the end of each course—in the final workshop of the general studies course, students in groups of six discuss their experiences with the futures scenario assignment. Round tables, a common assessment strategy in middle years of schooling, are a public exhibition of learning described by the Australian National School Network (ANSN) (2001), and were used as the final assessment in the numeracy course. Finally, we looked at the ways the scenario writing

Table 1 A summary of the evaluation tools

Evaluation tools	Description
Scenario assessment (SA)	Assessment of futures scenarios against assessment criteria.
Course evaluation (CE)	Online course evaluation completed voluntarily and anonymously by students at the end of the course. Students had the opportunity to complete a 10-question Likert scale questionnaire and give free responses to questions about the quality of the course and suggest changes/improvements.
Student reflective writing on scenario writing (SR)	Two questions answered either in a 200-word written reflective piece and/or in a focus group discussion: •How did you go about constructing your futures scenario? •What value is there, for you, in writing futures scenarios?
Focus group discussion (FG) (2008, 2009 and 2010)	Small group discussion around six questions, audio-recorded and transcribed: •What strategies did you use to prepare for the writing of the futures scenario? •What strategies did you use to write the futures scenario? •In what ways did the writing of the futures scenario support learning? •How did you select the genre used for the scenario? •How did the quadrant model[a] support/not support your scenario writing? •In what ways have you changed your behaviour or are committed to change your behaviour?
Round tables (RT)	Part of an assessment task for the numeracy course, with pairs of students presenting their future scenario to a group of six students.

[a] The integral quadrants model is based on our awareness of the interrelatedness and interdependence of all phenomena—cultural (the internal world of communities), the internal world of community members (spiritual/psychological) and the external world of natural systems (ecological and community) and the things that make them up (Wilber 2006)

changed students' own ways of thinking and behaving as evident from student written responses and focus groups. Evidence as to whether or not students enact the scenarios they construct in their lives and teaching contexts will require a more extensive study, but there were certainly statements of commitment to make changes.

In this paper, we draw on data from the *Atmosphere and Climate* courses taught in the years 2007–2010 (Lloyd 2010, 2011)[1] and numeracy courses taught between 2011 and 2013. Table 1 provides a summary of the evaluation tools we used. Table 2 provides student numbers completing the futures scenario as part of their *Atmosphere and Climate* course. Numeracy was a core course and each year numbers oscillated between 110 and 130.

It is not our aim in bringing the data and their interpretation together in this evaluation to predict or generalise but to help come to a better understanding of the value of scenario writing for deep learning and the development of foresight. The degree to which our interpretation 'fits' and 'works' (Guba and Lincoln 1989) was maximised within the limits and resources of the study by valuing students' work, listening to their explanations, and seeking confirmation of our interpretations. Our analysis is a creative narrative with the participants. Constructivist ethnographers do not attempt to eliminate the effects of their presence on the data or on the research setting, but are clear that they are part of the setting under study.

[1] Due to staff changes, data was not collected for *Atmosphere and Climate* after 2010.

Table 2 Students taking part in the general studies futures scenario, 2007 to 2010

Year	Student numbers for 2007 to 2010	
	Female	Male
2007	28	19
2008	32	16
2009	48	19
2010	25	13
Total, 200	133	67

Findings and Discussion

We were aware of the challenges of introducing students to futures scenario writing without them having prior experiences in futures thinking and exposure to the range of futures concepts and techniques that go with it. Futures work cuts across all subject disciplines—that is, it is integral in nature and ideally needs to be pervasive through a developmental process in teacher education programmes. The lack of connectivity between courses makes this difficult, particularly if futures work is not valued. Nevertheless, we have been pleased with the way students have taken to this futures assignment and the quality of their work. Our findings mainly focus on futures scenarios in a science general studies course (Atmosphere and Climate). This is complemented by a descriptive example of using futures scenarios in a numeracy curriculum course.

Futures Scenarios in Science General Studies Courses

Students who select science as one of their specialities in the bachelor of education (primary and middle schooling) are required to do four general studies courses in science. Two courses are designed and delivered by the science/mathematics team, *Atmosphere and Climate* and *Astronomy and the Universe*. These both explicitly include futures work in the form of futures scenarios as final assignments (for examples of student work, see Lloyd 2010; Lloyd et al. 2010). We have analysed the scenario writing and focus group discussions to record the impact on students' own ways of thinking and behaving. To organise the data, we have used the research questions and the following structure:

- Futures scenarios and learning
- Futures scenarios and personal empowerment
- Futures scenarios and personal behaviour
- Futures scenarios as a useful pedagogical practice.

Futures Scenarios and Learning

The course evaluation instrument (CE) and students' reflections (SR) were used to gauge the quality of the learning environment and consistently indicated it to be conducive to productive learning. For example, in response to the statement 'Overall I was satisfied with the quality of

this course', 86% of students who responded agreed or strongly agreed. Students' reflective writing also identifies satisfaction with the learning in these courses: Sally (SR, 2010) wrote:

> At the beginning of the course when we were first presented with the challenge of writing a futures scenario I was a little worried that I would not have sufficient knowledge about writing or predicting what life is going to be like in the future. However, after completing the reading, being involved in all workshops my knowledge on climate change grew immensely.

Natasha (SR, 2010) noted that:

> The construction of my futures scenario was challenging on many levels. I spent many hours contemplating the format, deliberating on the content and most importantly ensuring I compiled my story (letter) in an authentic, creative and accurate manner.

Integrally informed scenario writing (Lloyd 2007b) by its very nature requires students to draw on a number of areas of learning—science, history, English (literacy), ethics—and the use of a number of lines of development, such as cognitive, affective, moral, conative and creative. For example, Cathy (SR, 2010) found she needed to be "creative" rather than "scientific" to develop her futures scenario:

> I found myself only after a few sentences stuck and didn't know what else to do! After the formative assessment of the scenario, Sarah told me that the way I was writing it was too scientific and that it needed to be more creative and [I could] then later put the scientific information in the endnotes. I was able to completely restart my Future Scenario from that and wrote a children's story instead.

Ester (SR, 2010) wrote that "I enjoyed being creative and being able to share my opinion for the future".

Conceptual development, the cognitive processes of higher order thinking of application, analysis, synthesis and evaluation/reflection, and foresight are identifiable in students' work and students themselves recognise them. We use this selection of ways of thinking to illustrate the value of futures scenario writing in students' intellectual development. The futures scenario assignment provided an opportunity for students to review their learning and apply it to a novel situation. Examples that demonstrate this include the following:

> It was good to work through the readings again and it cleared a few misconceptions I had before. Gave me a good opportunity to deepen my knowledge about climate change and its effects. (CE, 2008)

> It made us think out of the square, we weren't told what we had to write, we had to work that out ourselves. It gave us a chance to be creative. (CE, 2007)

In the area of *conceptual development*, 85% of students strongly agreed or agreed with the evaluation statement (CE) that 'The course developed my understanding of concepts and principles'. Students' comments indicated this conceptual learning was assisted by the scenario assignment:

> Also, reading all the readings, you're more critically reading it now because it's for a purpose. (CE, 2009)

Application is about taking knowledge and applying it to a novel/new situation; the futures scenario assignment provided an ideal way to do this as evident in Table 3 and the following comments:

> It gave me the opportunity to try and look into the future and see what may be. (CE, 2007)
> It helped me recognise what might be happening in the future and how I can prepare myself for it. (CE, 2010)
> The future scenario aspect of the course … provides a chance to think about how we would like the world to be in the future and the ways in which that could be achieved. (CE, 2007)

The futures scenario extracts (Tables 3, 4 and 5) have been taken from an article (Lloyd et al. 2010) co-authored with three students who took the *Atmosphere and Climate* general study course and provide good illustrative examples of possible and preferred futures and creative ways students approached the task. Table 3 is Anna's introduction to a future scenario of Australia's climate in the year 2050. It uses Dorothea Mackeller's poem to critique global warming and its effects on Australia. It is a powerful example of taking new understandings and applying them to a novel situation.

Analysis is about critical examination of compound/complex situations and the recognition of the parts that make them up in order to bring out essential elements or structures. Students recognised the need to differentiate aspects of their learning before they could integrate them into a futures scenario. For example, one student said that, "It made me analyze and develop a deeper understanding of the topic involved" and "look deeper into different issues in society,

Table 3 Future scenarios demonstrating application

'Weather for Tuesday September 17, fine and sunny 12′ High: 35 Low: 18'
The Australian
www.theAustralian.com.au
The quality Australian—owned and operated by the Australian people.
34 pages vol 66 No. 207 Tuesday September 12, 2050
Registered as a newspaper in Australia, price: $4.50
Australia, 2000–2050
A reflection of the last fifty years we must never forget.
Poet or prophet?
I love a sunburnt country,
A land of sweeping plains,
Of rugged mountain ranges,
Of droughts and flooding rains.
I love her far horizons,
I love her jewel sea,
Her beauty and her terror
The wide brown land for me. Dorothea Mackellar (1885–1968): 1904
Would Dorothea Mackellar ever have guessed that the Australia she described in her reflection on her beloved country almost 150 years ago would become such a terrifying reality within the next century and beyond, with the effects of global warming devastating our long-envied lifestyle to such an extent that it was no longer possible to identity anything that remotely resembled the 'great Aussie way of life'?

Table 4 Future scenario: synthesis

A Krill's diary, 25 January 2056

Strange things are happening here in the Southern Ocean and I feel it necessary to start a diary as I am unsure how much longer our species will survive. To begin, let me introduce myself. My name is Earl and I am a Krill, or sometimes referred to as a low life. My family has lived in the Southern Ocean for as long as we can remember but vast numbers of our species have gone missing and are feared dead. Over the past eighty years our population has been reduced by 80 % and it is my mission to find out why. This is a dangerous mission as starvation is a big threat among other species due to the decline in our population. It has been heard on the ice caps that the penguins are blaming the seals and the seals are blaming the whales. The only species that has an alibi is the phytoplankton—they are vegetarians. However I rule no species out—my mission is to look in every deep corner of this ocean and solve this mystery. If I fail to find a solution, it is feared that this will be the end of our species and who knows what will happen to the other animals that rely on us for their food… wish me luck!

and understand what the situation had stemmed from" (CE, 2007). Another wrote, "To start off planning my assignment I started looking at others' future scenarios. I read about four or five before I started. I listed what I was going to have in each of my paragraphs, one about animals, flora, sea level rising, temperature increase and how things have adapted" (John, SR, 2010).

Synthesis is putting together or combining ideas into a complex whole, which of course is the aim of an integrally informed futures scenario. The high quality of the futures scenarios is a strong indicator of students' ability to connect their conceptual learning with personal, social and cultural dimensions. As they reported:

> It was a way of summarizing the ideas from the readings and also the ideas we talked about in the course like reading them altogether into one piece of work that we could reflect on. But without doing the scenario I would not have gone back and read those areas' (FG, 2008);
>
> It's sort of makes you think that everything is interconnected, like if you do the air quality or something then that's going to affect the temperature (and) all other sorts of connections (sic).

Other students remarked that writing futures scenarios;

> helped because we had to use learning from the whole course-it helped to kind of fit everything together. So I realised that one topic connected with another—helped me see that more easily (sic)' (FG, 2008);
>
> It brought everything that we had addressed in the course together in one final assignment. It was an excellent way to finish a course such as this one (CE, 2010).

An example of synthesis in which new understandings can be usefully applied is illustrated in the introduction to Lisa's scenario, set 50 years in the future (Table 4). It is written from an animal's perspective on global warming and the influence it is having on Antarctic ecosystems.

Table 5 Futures scenario developing foresight

Our extra crispy climate

'Did you order the Original Recipe or Extra Crispy?'—Foghorn Leghorn, Space Jam (1990)

It seems that during the 20th century our baby boomer parents were very much like Foghorn Leghorn, one of my favourite childhood cartoon characters. They got so caught up in the fun and excitement of being competitive and winning that trophy of success that they didn't realise how unsustainable their obsession with success was. In typical parent fashion, they had pre-ordered us a steaming plate of extra hot climate, never even bothering to ask us what we would like to eat. They chose an 'Extra Crispy' world for us to live in, over the 'Original Recipe' climate that they had enjoyed.

This scenario has been written as a story to engage upper-primary students in the science of global warming (Lloyd et al. 2010).

In futures scenario writing, *evaluation/reflection* is about both assessing the value of the scenario itself and the process of constructing the scenario. That is, 'Is the scenario useful?' and 'Is the scenario process useful?'. The following illustrates recognition of the usefulness of the scenario:

> The future scenario … provides a chance to think about how we would like the world to be in the future and the ways in which that could be achieved' (CE, 2007).

The following illustrates the valuing of the futures scenario process itself:

> To complete my assignment 3 I had to do a lot of preparation. This included mapping out my integral quadrants information which took me a very long time. I found out that once I mapped it out more and more information just fell into place because relationships between quadrants developed and in the end it helped the flow of my scenario (Jacklyn, SR, 2010)

> I hadn't realized how many of the earth's systems were connected to each other and reliant on each other e.g. wind, ocean and sun. I also hadn't realised how much politics plays in the decisions of the future of our wellbeing. This insight was worth developing' (CE, 2010).

The learning demonstrated by students goes beyond the cognitive. There is evidence in the above examples that the affective and ethical lines of development are also drawn on and developed. James' (SR, 2010) response illustrates both of these aspects:

> It has shown me many new aspects and information about the weather, climate and atmosphere that I never knew before starting. It has made me think about how I am using the earth I live on every day, and what impacts I am making on it, which the next generation will experience. Before I make an action, I should be thinking about the reaction it has on the environment and the earth itself.

Students recognised that futures scenario writing assisted the development of *foresight*, "the process of attempting to broaden the boundaries of perception by careful futures scanning and the clarification of emerging situations" (Slaughter 1995a, p. 48). Examples of their comments include:

> It also gave me ideas for the future like what would happen if I don't start changing or other people don't start changing as well' (FG, 2007);

> It helped me to visualize how I see the future more thoroughly and also stimulated my thinking about how various choices and directions interact to make one kind of scenario'(FG, 2008);

> I want my grandchildren to enjoy the things that I enjoy;

> It just got me thinking about long-term planning because really I'm somebody more like a short-term planning guy' (FG, 2008);

> It provided an opportunity to explore how life might be in 30 years' time and the changes we can make now to ensure climate mitigation takes place… Throughout the writing process I utilized visioning skills as learnt in the workshop, to assist me with creating what my future would look like, and the changes that had to occur' (FG, 2010).

The development of foresight is illustrated in Table 5, where Louise critiques current lifestyle and community values in her futures scenario on global warming (Lloyd et al. 2010).

Futures Scenarios and Personal Empowerment

Knowing more about the world and developing foresight are both empowering processes, but there is further evidence that the developing of normative integral futures scenarios puts students in a better/different space in other ways. Writing from a first-person perspective provides for aspects not often possible in (science) academic writing. Natalie (FG, 2010) chose to do her "futures scenario as journal entries as I thought this would be the easiest option and also it enabled me to give a more personal approach". The inclusive nature of personal future scenarios encourages students to include their personal feelings and values and those of the community to which they belong, as illustrated in Table 5.

Students were affected in quite powerful ways and the scenario writing process connected them to these concerns. Examples that demonstrate this include the following:

> I described a community that I would like to belong to, and that I would like my family to grow up with Leonie (SR, 2010)
> It's not creating something that is completely imaginative; so you're sort of using that science knowledge to think about actually what could actually happen, what could actually be constructed (FG, 2009)
> As I've just said, about keeping it real, you are creating a scenario that could happen (FG, 2010).

What students discover in the scenario writing process is also sometimes confronting:

> What I found hard was how I personally can change what is going to happen. Like for the future the actions you are going to take to put the end to something. I've found that really really hard. That's why I think I'm struggling with futures' (FG, 2009).

Others see the process as preparing them to interpret the world in new ways:

> It allowed me to present the information in a way that I wanted to as well as to see the possibilities that could be achieved whilst fighting climate change' (CE, 2010).

Dylan (CE, 2010) did some serious thinking about our political leaders

> … by looking back on recent events, such as the national election and imagining what life in Australia might have been like had we elected a Prime Minister that didn't believe in Climate Change

, and

> It has also extended my learning to have a more critical view of the information presented in media, or especially by political members.

Some of the most moving stories came from rural students who explored the prospects for their parents' (and future generations') farming life and their rural communities:

> When I started planning my story I chose to do my home town and what it would be like in fifty years' time (CE, 2010).

> Jordan (CE, 2010), decided to write it about the farmers and how they have adapted with the limited supply of water and how the long dry periods have forced them into the genetically modified crops.

We have left the concluding comment for this section to Jacklyn (CE, 2010), who wrote that the futures scenario writing

> helped me recognize what might be happening in the future and how I can prepare myself for it. Overall I found the course to be an eye opener and I have recommended it to a lot of peers.

This indicates the high value placed on developing futures scenarios for this student.

Futures Scenarios and Personal Behaviour

Futures is not just about thinking but it is also about taking action. A few students indicated that they were already environmentally aware and were trying to live more sustainably: "we already do a lot" (CE, 2008). Others indicated that they were now more aware and prepared to be action orientated:

> I've taken an active interest in the effects that my behaviour and what others' behaviour is (FG, 2008);
> I can operate with good background knowledge now and also I can change my behaviours to help the future (FG, 2008).

In focus groups students talked about catching public transport, car pooling and turning off lights at the powerpoint. Students wanted to become politically more active:

> I can see the 'power of one' and the importance of sharing information if we are going to make effective changes for a sustainable future (FG, 2007).

They felt far better informed to make decisions for themselves and confident to relay their understandings to others: Natalie (CE 2010), for example,

> It has definitely opened my eyes to climate change and has educated me in ways I can help better our planet, by reducing my carbon footprint (Natalie, CE 2010)
> It has altered the way in which I look at my energy consumption, made me more cautious of the way I use cars, waste electricity, etc. (CE, 2009).

A Useful Pedagogical Practice

Many students found the futures scenario assignment a useful pedagogical practice, refreshing and enjoyable as illustrated in the three scenario examples (Tables 3, 4 and 5) and in the following:

> An interesting way of writing factual information in essay form, refreshing, forces you to research the subject (CE, 2009);
> It wasn't as hard as I imagined. I very much enjoyed reading and collecting the information as it was very interesting education. The word count appeared too much, however when I began writing up my report, I was carried away and could not stop writing. Overall it was a great assignment— I learnt a lot about climate change and have realized how important it is to live sustainably (CE, 2010);
> I found it interesting to do an assignment like this at uni — possibly for the first time in 3 years I have actually got to use my imagination rather than just pure facts (CE, 2009);
> I found that this assignment was useful in the fact that it helped me to think 'outside the box' about topics that will undoubtedly have an effect on all of us in the future (CE, 2009).

Our analysis of student data suggests that as a result of our focus on future scenarios, students could see the value of foresight as an attribute to develop in the students they will teach. For example, they made statements such as the following:

> As a future educator I can use this to help my class in understanding how climate change is working and how it's affecting our environment (CE, 2007);
> I think there are lots of science … type topics that the kids could develop future scenarios for, using the knowledge that they have gained (CE, 2007).

Explicit links were therefore made to the value of using the pedagogical practice of scenario writing in their classrooms as early career teachers.

An Illustrative Pedagogical Example: a Futures Scenario Experience for a Numeracy Curriculum Course

A focus in the final curriculum course is exploring transdisciplinary approaches to planning for learning, as mentioned earlier. In this course an example of a transdisciplinary unit of work is modelled through a series of on campus workshops titled *A Place in Time*. The fourth year numeracy cohort in 2013 (N=119) students used three lenses—scientific, mathematical and sustainability—to gather data and develop a relationship with a significant tree on campus. The students demonstrate their knowledge and understanding through a key summative assessment task which involved presenting a holistic view with six of their peers at a roundtable. Examples from the mathematical lens included estimating and measuring the surface area of the shade at three different times of the day, drawing an accurate map of the location of the tree and estimating the number of leaves. For science, they collected data about percentage cloud cover three different days a fortnight apart; analysed the soil, describing pH, colour and texture; and observed the interdependence between plants and animals. Getting close and personal with their place is the aim of using a sustainability lens. This supports the ideas of Suzuki (1990, 2010) who says that if you are connected to the natural world then you are more likely to look after it. The components of the sustainability lens used to explore their place include spaceship earth, a futures scenario, indigenous perspectives and taking action.

This paper focuses on the future scenario component. The students were introduced to the idea of future scenarios by being exposed to Schwartz (author of *The Art of the Long View* quoted in Snoek 2003) who states that scenarios are a tool for helping us to take a long view in a world of great uncertainty. In this way, the result of scenario planning is not a more accurate picture of tomorrow but it might lead to better thinking and reflection on current trends and developments and an ongoing strategic conversation about the future (Lloyd 2003). The future scenario required the pre-service teachers to envisage their tree site in 20 years time and to attempt to draw this. They then used their possible futures drawing as a starting point to write a 100-word futures scenario. They needed to consider (1) the physical and biological aspects of place, (2) the social and cultural aspects of place and (3) the spirit of place.

Each pair of pre-service teachers was given half an hour to share their findings at a roundtable (RT) using the three lenses. The criteria for the assessment encouraged pre-service teachers to be creative about how they presented. They constructed models, undertook role plays, presented posters and used ICTs such as blogs, Facebook, prezzie and powerpoint. The future scenario was one of the criteria that they needed to address. It required them to consider physical/biological, socio/cultural and spiritual aspects. They try to visualise how the

Table 6 A representative example of a futures scenario

Futures Scenario—10 Year Forecast
Expansion of science buildings and the redevelopment of surrounding areas.
By 2024, the Science Buildings and surrounding areas will have been remodelled in keeping with the innovative construction of the MM Building (currently most recent development). In an effort to embrace diversity and to foster relationships with the Asian Community, the university will have decided to build a Japanese inspired Zen garden next to Science Building. Unfortunately this will mean that the trees and the native vegetation next to the Science Building have to be removed. The Zen garden will be a tranquil and serene space for students to sit and relax between classes.
100 % online university
By 2024, all University operations will be 100 % online, meaning that the Mawson Lakes Campus will no longer exist. The university will have sold the land to make way for a new housing redevelopment in the northern suburbs. Before clearing the site, the developers will have decided to save some of the mature trees for replantation in a different area. Our plant "Flor" will be saved, but the amount of open space will be diminished.
Protection of native vegetation
It's 2024 and nothing has changed structurally to the Mawson Lakes Campus, however it looks vastly different to how it did in 2014. The native trees and shrubs have fully matured. On site gardeners ensure that the grassed areas and garden beds are kept in good condition, with the help of a new and improved recycled-water irrigation system.

part of the university campus they occupy may change over a 20-year period and are encouraged to adopt a utopian rather than dystopian worldview. Two representative examples of such scenarios produced by pre-service teachers are included below.

The first future scenario (Table 6) shows how in the future a Zen garden for relaxation has replaced native vegetation. It was interesting to note that students' rationale for this was fostering the relationships between the university and Asian students and members of the Asian community. In the future scenario, there is no on-campus attendance or buildings, with all learning taking place online and on-site gardeners looking after the legacy left behind from the university.

The second representative example of a futures scenario is written as a letter sent to all students from the Head of Environmental Science informing them of changes that will impact on them as plans are implemented to undertake restorative practices to improve the university grounds (Table 7).

Both scenarios show that pre-service teachers were able to acknowledge the past and project into the future. In both scenarios the future sites have been significantly changed from the present time, where monolithic buildings impact on the little remaining remnant native vegetation and consuming open spaces on campus over the four years of their undergraduate degree. The scenarios include increased open space, areas of solitude and planting of indigenous species. What we like about these scenarios is that they project a slightly hopeful possible future.

Apart from developing confidence in using a powerful pedagogical device to engage pre-service teachers in meaningful science, a futures studies approach that incorporates scenario-building also provides pre-service teachers with a strategy they can use as educational leaders at the sites where they will work after graduation. The three students who collaborated with us to write a journal article for science teachers have shown leadership in innovative futures work even before they have started their lifetime work as science educators.

Table 7 Example of social action in the form of a letter

To: Students of the University …,

The university… is undergoing an environmental make-over. Many of the university's trees have been here since before the land was built on in 1970 by the South Australian Institute of Technology. It is with deep regret that I must inform you that we will be replacing many of the old trees. As the summer and winter months are being accompanied by more extreme weather events we are no longer able to care for many of the old trees on the campus. Consequently, they are becoming hazardous as branches fall without warning. As there is little food or shelter available from these dying trees the native fauna is suffering. We realise that we need to keep our university's ecological footprint minimal. To help sustain the wildlife of the Mawson Lakes area we will be planting a range of mature native trees. The area outside the SCT building will be re-vegetated with a new Eucalyptus Gracilis (Yorrell) tree and many more native shrubs and bushes. We hope the native wildlife will return to the university once again with the plantation of native trees and shrubs. Our landscapers and gardeners are also working hard to include students' ideas into the new garden areas.

If you would like to propose any ideas to our landscapers and gardeners, contact us at GardenRenovations@unisa.edu.au.

We look forward to seeing a healthy university once again.

Adrian Smith, Head of the Environmental Science Department

Concluding Insights

In this paper, we have provided evidence that helps answer our research questions, namely that futures scenario construction supports and enriches learning, that it assists students in decision-making, and that futures scenario work in science education is an effective pedagogical practice. From our work with pre-service teachers and situating this within the relevant literature, we conclude with reasons why futures studies needs to be an explicit dimension of learning and, in particular, science learning, all of which are included within Henderson's (1998) argument that, "education for a humane future is the most important enterprise of human culture, our investment in the very survival and evolution of our species" (p. 14).

Firstly, we conclude that the construction of futures scenarios as an integrated aspect of science learning assists students to develop their futures thinking. Futures tools such as scenario development "help us to understand the range of possibilities we face and to choose and create the future we want" (Bezold 2010, p. 169). Future scenarios provide a context in which new understandings can be usefully applied. Students' skills and abilities are brought to bear upon open-ended issues that need resolution for futures worth living for, and they learn to construct knowledge as well as use current knowledge—"In a world of accelerating change, an ability to identify and proactively plan for plausible futures is of ever greater importance" (Hajkowicz 2015, p. 7).

Secondly, students already have images of possible futures that form an aspect of their prior knowledge and, what is more, as demonstrated by Eckersley (2002), Hicks (2002), Hutchinson (1996), Lloyd (2001) and others, they do have concerns for futures. Masini (1993) argues that futures thinking is a way of conceptualising life, our everyday decisions and actions—"It is a way of thinking about the world, about society, about the relationship of society with nature" (p. 3). We suggest that science education, because of its connection to so many student concerns, has a role to play in helping students articulate these concerns and work towards preferred futures. The challenge for educators is preventing students from losing "their belief in the future and in their own possibilities to influence it" (Rubin 2013, p. S38).

Thirdly, foresight is a natural human tendency that is not usually explicitly developed in science classrooms. Slaughter (2004) points out "that short-term thinking has become the

norm" (p. 1) yet we live in a times of rapid change and uncertainty which our best scientific organisations such as Australia's CSIRO are working diligently to explore (Goldie and Betts 2014; Hajkowicz 2015). *Australia21*'s 'The Australian youth forum asks the next big question about the Future' found that young people were interested in taking an active role in building a sustainable future, both environmentally and socially, yet most found it very difficult to name ways in which they could personally contribute to a wider agenda of constructing preferred futures and actively link the personal to the local to the global (Reeder et al. 2010).

Fourthly, we live at a critical juncture in the history of our species because of conditions of unsustainable living by a significant proportion of the world population in the overdeveloped world (Ehrlich and Ehrlich 2014). Earth has moved into the Anthropocene and its sixth extinction (Kolbert 2014) and a lot of imaginative thinking and acting is needed if humans are to live well and harmoniously with other species. Raskin (2013) argues that while we are in a world at risk, we are also capable of "offering a compelling vision of a better path" where the "basis for hope rests on two kinds of arguments, one scientific, the other historical" (p. 1). Such a view requires that science education contributes to this hopeful vision through an understanding of how the natural world works and applying this understanding to actions that provide "pragmatic hope … the antidote to dystopian despair".

Fifthly, all education—the what, how, why, place and physical environment of learning—originates from some social image of anticipated futures. This requires that our students actively participate not only in the knowledge base of creating desired futures but also participate in envisioning the futures they desire (Gidley and Inayatullah 2002). Hutchinson and Herborn (2012) make the connection between futures education, peace and our urban landscapes" "They invite wide-ranging discussion on issues such as the futures of urban design, public transport, environmental justice, active citizenship and nonviolent movements of social change" (p. 24)—all areas to which a futures-orientated science programme can significantly contribute. Science education has a lot to offer in these areas in terms of understanding how the natural world works and how humans can sustainably live within healthy ecosystems.

Finally, a futures perspective to science learning is integrative. It requires "a broad, integrated, and holistic view" and "its social and personal significance" (Eckersley 2002, p. 33). Lovelock (2014) argues that "knowledge of the Earth's surface environment and a feeling for the natural environment should be part of our culture. I think it right that we hold it emotionally as well as rationally" (p. 124). Futures scenario writing draws from many traditional subject areas are opens up relationships between factual and value questions and is empowering by providing the opportunity to exercise significant control over personal futures. Slaughter (2002) argues that "we require an educational system that can critically mediate between past and future and take full account, not merely of some aspects of body and brain, but of the whole inner person and its spectrum of needs" (p. 28). Such futures work provides for "a different way of learning and being that draws on the full spectrum of human potential of cognition, aesthetic, emotional, spiritual, and kinaesthetic intelligences in order to create a wiser global society" (Awbrey et al. 2006, p. 1). Futures studies can increase student engagement, develop students' values discourse, foster students' analytical and critical thinking skills and empower individuals and communities to envisage, value and work towards alternative futures (Jones et al. 2012).

Taken together, these six reasons provide an overwhelming justification for including a futures dimension in science education. Given the few references to futures thinking in the science learning area, the general capabilities and cross-curriculum perspectives in the Australian Curriculum this study is critical for informing future curriculum directions. Unless the current narrow and technical representation of futures is developed to reflect a

more critical orientation, then in our view, this will result in a less uptake of futures thinking in Australian schools.

In our courses, futures work has provided an effective pedagogical practice for early career teachers. The futures scenario tasks have added an additional element to a transdisciplinary/integral approach to learning that we believe science educators need to employ to connect science to students' lived experiences in nature, culture and self. The future (the time dimension) is a place in which students at all levels of schooling can apply their science learning. A futures dimension provides purpose for learning science other than for its intrinsic interest. A futures dimension to science learning provides new places for students to apply their science learning, and inspiration to search for new understandings for their personal needs, community needs and the needs of future generations. A disposition to futures can also provide teachers with the tools to explore scenarios for a preferred vision of science education and to bring them to life.

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