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# Developing Students' Futures Thinking in Science Education

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**Abstract** Futures thinking involves a structured exploration into how society and its physical and cultural environment could be shaped in the future. In science education, an exploration of socio-scientific issues offers significant scope for including such futures thinking. Arguments for doing so include increasing student engagement, developing students' values discourse, fostering students' analytical and critical thinking skills, and empowering individuals and communities to envisage, value, and work towards alternative futures. This paper develops a conceptual framework to support teachers' planning and students' futures thinking in the context of socio-scientific issues. The key components of the framework include understanding the current situation, analysing relevant trends, identifying drivers, exploring possible and probable futures, and selecting preferable futures. Each component is explored at a personal, local, national, and global level. The framework was implemented and evaluated in three classrooms across Years 4–12 (8 to 16-year olds) and findings suggest it has the potential to support teachers in designing engaging science programmes in which futures thinking skills can be developed.

**Keywords** Classroom research · Futures thinking · Primary · Secondary · Socio-scientific issues · Teacher professional learning

## Introduction

The futures field of study, variously called futures studies, the futures field, futures research, futuristics, prospective studies, or prognostics (Bell 1996), has its origins in the strategic

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planning of governments and large corporations. For example, New Zealand's Ministry of Research, Science & Technology [MoRST], now the Ministry of Science and Innovation, uses a 'futurewatch' methodology—scanning, analysing and disseminating information on emerging developments to provide early alerts of new opportunities and issues—particularly in areas that have complex pathways of development and potentially transformational implications across the economy, environment, and society (MoRST 2003). All reports (e.g., MoRST 2005, 2006, 2009) draw on the expertise of respected scientists, demonstrating how the role of 'scientist' is expanding to explicitly consider the implications of scientific advancements for society as a whole.

Futures thinking is also starting 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) and the South Australian curriculum framework identifies futures as one of five essential learnings permeating the key learning areas (Department of Education Training and Employment 2001). At the same time, science curricula world-wide have been extended to include notions related to the nature of science, and the science-technology-society-environment (STSE) movement has emphasised the teaching and learning of scientific developments in their social, cultural, economic, and political contexts (e.g., Fensham 1988; Pedretti 2005). Within this, the use of socio-scientific issues (SSI) has been advocated as an approach in order to focus specifically on the controversial nature of many scientific and technological developments, presenting opportunities for moral and ethical issues to be considered (Zeidler et al. 2005; Zeidler and Nichols 2009).

This paper explores the potential for futures thinking to enhance teaching and learning in school science, firstly by providing an overview of the futures field and where it fits within science education, and secondly by introducing a conceptual framework to incorporate futures concepts into SSI-based programmes. This conceptual framework, developed later in the paper, includes five components—understanding the current situation, analysing relevant trends, identifying drivers, exploring possible and probable futures, and selecting preferable futures—each explored at a personal, local, national, and global level. The implementation and evaluation of the framework is explored in three classrooms across Years 4–12 (8 to 16-year olds) to determine whether futures-focused activities can be meaningfully incorporated into science programmes.

## Using Socio-scientific Issues to Enhance Science Education

Traditional forms of science education have tended to concentrate on students who wish to pursue a career in science, thus serving only a particular group of students. Hodson (2003) argues for broader citizen participation, promoting the practical utility of scientific knowledge and connecting it with personal and social aspects. The use of SSI as a context for teaching science concepts can enhance student interest in science and its wider applications, increasing student motivation and enjoyment of science (Fensham 2007). Further, by being more willing to engage with the relevant scientific concepts and rework them in the context of a particular socio-scientific issue, students can see how their science understanding might help shape the world in which they live. This may ultimately lead to action competence (Jensen and Schnack 2006). The use of relevant, authentic issues also provides a stimulus for dialogue, with a concomitant development and use of the language of science (Roth 2005) and may foster curiosity and inquiry as a learning approach and as a learning outcome. In addition, critical thinking and moral reasoning may be enhanced (Simmons and Zeidler 2003).

A further reason for engaging students in SSI-based learning is to enhance their understanding of the nature of science. As Hodson (2009) argues: "Because SSI are often located in disputed frontier science (or science-in-the-making) rather than in established textbook science, knowledge and understanding *about* science is crucial" (p. 270). He goes on to point out that the interaction between students' NOS knowledge and the way they address SSI is complex and reflexive: "more sophisticated NOS views open up new possibilities for scrutinising SSI; engagement with important and personally significant SSI enhances and refines NOS understanding" (p. 270). This is particularly salient when considering futures aspects of an issue. As Osborne et al. (2001) point out:

> Pupils should appreciate why much scientific knowledge, particularly that taught in school science, is well established and beyond reasonable doubt, and why other scientific knowledge is more open to legitimate doubt. It should also be explained that current scientific knowledge is the best we have but may be subject to change in the future, given new evidence or new interpretations of old evidence. (p. 49)

Such 'science-in-the-making' (Latour 1987) tends to be emphasised within controversial SSI (Simmons and Zeidler 2003), and has potential to significantly influence our collective futures.

Osborne and Collins (2000) report that it is the futures focus of contemporary socio-scientific topics that many pupils find most alluring, and Lloyd and Wallace (2004) suggest that since students' futures images often contain aspects that intersect with the world of conceptual science, these images constitute prior knowledge that can influence motivation and conceptual development in science classrooms. However, the futures aspects appear to be largely implicit within many SSI programmes, and we advocate for a much more overt inclusion in order to further enhance teaching and learning opportunities in school science. For example, Carter and Smith (1997, 2003) argue that relevant and socially-critical science education that incorporates a futures perspective provides students with the means to examine and problematise their views and concerns about socio-scientific issues. Lloyd and Wallace concur, and go on to advocate for the inclusion of a futures perspective in science education as a way of addressing Hodson's (2003) notion that local and global political perspectives form an important aspect of scientific literacy. Paige et al. (2008) argue that a futures, issues-based approach provides students with opportunities to evaluate the positive and negative impacts of science and technology on society and to explore possible solutions to perceived future concerns. Despite these advantages for including futures approaches in SSI-based programmes, the structured inclusion of futures thinking in such programmes has not been well studied. This paper contributes to the field by developing and evaluating a conceptual framework to support students' futures thinking in the context of SSI.

## Futures Thinking in Science and Science Classrooms

Futures thinking is aimed at detecting, inventing, analysing and evaluating possible, probable and preferable futures (Amara 1981), the plurality of the name stressing the range of future options and possibilities and notions of choices and alternatives (Slaughter 1995). The following perceptions are important: the future world will likely differ in many respects from the present world; the future is not fixed, but consists of a variety of alternatives;

people are responsible for choosing between alternatives; and small changes can become major changes over time (Cornish 1977). A British meta-analysis of 53 futures studies carried out by governments and business (DERA 2001) found that most futures work incorporates 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 or environmental change), wild cards (high-impact, low-probability events, e.g., the Chernobyl disaster), and outcomes (possibilities and scenarios).

Scenarios, developed as part of many futures projects, are understood to represent possibilities rather than predictions that can then be used as an exploratory tool or a tool for decision-making. Eames et al. (2000), for example, describe them as "pictures of future worlds that describe a *possibility space*—a set of plausible futures that span a range of conceivable outcomes" (p. 4). In exploratory scenarios, the thinking moves from the present towards futures that could conceivably evolve from the present. In contrast, scenarios that are normative, or strategic, move from an envisaged desirable future back to the present (Coates 1996). Rawnsley (2000), highlighting different levels of complexity in scenario development, identifies a continuum from contemporary to transformative worldviews, where a contemporary orientation relies largely on surface knowledge: descriptive knowledge of observable, evidential phenomena lacking the deeper analysis of causation or multiple interpretations of reality. In contrast, a transformative orientation not only locates knowledge (such as trends) within a community or culture, it also critiques how the values and power structures within the communities or cultures are framed and maintained. Thus, addressing an issue such as pollution would necessitate an appreciation of various interpretations of contributing factors (economic growth, job creation) by different communities (industry, those living in affected areas) as well as an analysis of the values and rights of the different communities—and how these are initiated and maintained.

There are several convincing reasons for incorporating futures thinking in science education programmes, including the fact that scientific and technological advances are fundamental to most people's perceptions of the future. For example, 79% of secondary students in a New Zealand study ($n=252$) mentioned that technology will have positive and negative impacts on the future (Otrel-Cass et al. 2009). In addition, futures studies can "take on the myths that technology and science are neutral, value free and objective and that technical expertise can solve every problem" (Lloyd and Wallace 2004, p. 160). Futures thinking as part of a SSI-focused science programme should therefore provide opportunities—through the building of possible, probable and preferable futures scenarios—for students to reflect on their own as well as others' values. For this reason, Dror (1996) argues that there must be values transparency; students need to identify underlying values, and this in turn requires improved moral reasoning and values discourse. This fits well with the *New Zealand Curriculum* (Ministry of Education 2007, p. 10), which requires that students learn about:

> their own values and those of others; different kinds of values, such as moral, social, cultural, aesthetic, and economic values; the values on which New Zealand's cultural and institutional traditions are based; [and] the values of other groups and cultures.

Other countries are similarly emphasising the need for holistic education and the development of the 'whole person'. To this end, Rawnsley (2000, p. 51) notes: "Educators who take their role seriously cannot easily separate discussions of possible, probable and preferable futures from a discussion of the ethics and criteria necessary for choosing between alternative futures."

The existence of multiple perspectives is also important. 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—what he calls an 'unknown world'—cannot be accomplished only 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. Values analysis approaches as used by Jarvis et al. (1998) provide explicit opportunities for students to consider multiple influences on decision-making from a critical perspective and should enable students to confront complexity and ambiguity.

In addition to developing students' discourse and analysis skills, introducing futures thinking in formal education provides opportunities for students to develop 'key competencies', recognised by the OECD project *Definition and Selection of Competencies (DeSeCo)* as being important for people to be able to contribute meaningfully to a well functioning society (Rychen and Salganik 2003). They have been incorporated in the *New Zealand Curriculum* (Ministry of Education 2007) as: thinking; using language, symbols, and texts; managing self; relating to others; and participating and contributing.

## Developing a Conceptual Framework for Supporting Futures Thinking in Science Classrooms

Few educational studies focus on frameworks specifically for enhancing students' futures thinking, although a range of practical workbooks with lesson plans and activities are available (e.g., Haas et al. 1987; Hicks 1994; Slaughter 1995). Rawnsley (2000) points out that many of the techniques, such as brainstorming and timelines, are not new but have simply been adapted or developed with a futures focus. Other activities are based on futures-specific tools, such as futures wheels (a single future event is placed at the centre of a wheel and direct effects of that event recorded in an outer ring, with succeeding rings used to record secondary or indirect effects); environmental scanning (to obtain specific information about trends and direct attention to unusual occurrences); and cross impact matrices (possible future events are written horizontally and vertically along a grid and each interaction assessed as to whether it is positive or negative).

Slaughter (1995) points out the importance of recognising underlying assumptions and how these influence the outcomes of such activities. His critical futures framework (Slaughter 1996) suggests that students consider individual, social, economic and political influences on decisions, and the implications, within specific science or technology contexts. Such an approach is considered by Lloyd and Wallace (2004) as providing a framework in which to value the strengths of both science and the humanities by facilitating learning that is integrative, holistic, and which includes a critique of values, worldviews, and ethics. They present a case study in which Year 9 students and undergraduate science teacher education students investigated the need for quality fresh water in South Australia. The teaching sequence involved identifying prior understandings (images of possible and probable futures, potential stakeholders); learning about technical aspects (freshwater ecology and the impacts of human actions); considering personal and community attitudes and activities; and shared decision making and pursuit of a preferred future. This framework therefore incorporated scenario development of possible and preferred futures, and the evaluation of alternatives. However, the elicitation of trends and drivers, highlighted earlier as being a significant component of futures work (DERA 2001), did not appear to be an explicit part of the Lloyd and Wallace exploration, and were noticeably missing from the list of futures vocabulary that their students developed, although past, present and possible future wetland management practices were considered. The importance of trends and drivers is also borne out in other studies, as demonstrated in their titles, for example, ‘Where will the world be in 2015? Analysis of trends and discontinuities’ (Maxwell 1998), ‘Global food projections to 2020: Emerging trends and alternative futures’ (Rosegrant et al. 2002), and ‘Past, current and future trends in tobacco use’ (Guindon and Boisclair 2003).

In order to broaden futures thinking in an SSI programme to explicitly include trend and driver analysis in scenario development and evaluation, we developed a conceptual framework that we subsequently implemented and evaluated in three classrooms (McKim et al. 2006). The framework takes into account the literature that identifies scenario models as an overarching methodology of futures studies requiring five key elements:

- an understanding of the current situation;
- identification of key trends;
- analysis of the relevant drivers;
- development of possible and probable future scenarios; and
- selection of preferable future(s).

Dominant drivers include demographics; environmental change; economics; science and technology; national and international governance; and perceptions, beliefs, values, and attitudes (Cabinet Office n.d.; DERA 2001). A similar set is identified by UNESCO (2002): increasing cultural differences; globalisation (where all countries are integrated into a global system of economic interdependence and cultural uniformity); increasing gender equity (leading to changes in social priorities and the way society is organised and functions); religious revival; increasing poverty; changes in technologies (where the increasing spread of computers in homes and work places is changing the way people live, work and play); and advances in biotechnology (including the use of genetic engineering to create new plant and animal breeds, as well as alter human genes). The inclusion of both ‘cultural differences’ and ‘cultural uniformity’ exemplifies the complexity of the issues that need to be considered. In addition, the cumulative effect of even small uncertainties means that the range of plausible future worlds is very large. A consideration of the social milieu—which both shapes, and is shaped by, the science or technology being investigated—is also critical (MoRST 2005).

In order to demonstrate how the five key elements listed above can be explored in a classroom environment, we proposed a conceptual framework that included an exploration of the following components using an inquiry methodology, that is, a student-centred pedagogy where teaching and learning begins with questions rather than statements:

- Understanding the current situation: *What happens now, and why?*
- Identifying key trends: *How does what happens now differ from what happened in the past, and why? Are the changes desirable? Who benefits? Who loses?*
- Analysing relevant drivers: *Are some of the changes (trends) related? What are the underlying causes for these changes?*
- Developing scenarios of possible and probable futures: *Are current trends and drivers likely to persist? How might they affect the future? What might change them?*
- Selecting, with justification, one or more preferable future(s): *What do you want to happen in the future and why?*

Each of these components can be contextualised to suit the particular topic being considered. Thus, for a study on future foods, "understanding the current situation" might include the following questions: *What do we eat now? Why do we eat these kinds of foods? Where do we get our foods from? How are the foods made more desirable? How are the foods packaged and transported?* etc.

In addition, each question is considered in relation to personal, local, national, and global perspectives. This encourages students to think beyond how the issue affects them personally, emphasising the critical role of the social context in futures thinking as well as the existence of multiple perspectives. An example of some of the variables that might be considered as part of a future foods learning context is presented in Table 1. Food is a common teaching context at all levels of the *New Zealand Curriculum* (Ministry of Education 2007) and one that is intrinsically of interest to children of all ages.

Complexity, or the view that the dynamics are non-linear and that outcomes of interactions cannot be predicted in advance (Capra 2002), is built into the model. To help teachers visualise this, a computer-mediated interactive graphic was developed (http://www.sciencelearn.org.nz/Thinking-Tools/Futures-thinking-tool), with each of the five components of futures thinking represented by a 'cone', or part of a sphere where each cone is in contact with, and influenced by, the other four. Each component also consists of personal, local, national, and global perspectives, making explicit the multiple social levels and the interactions between them. The number of variables possible within each area of the resulting matrix, for example 'local trend' or 'global driver', provides scope for a wide range of possibilities and it is postulated that the consideration of increasing numbers of variables within each area may provide an indication of progression.

In order to evaluate the usefulness of the model for developing a futures-oriented science classroom programme, a group of innovative teachers was invited to be part of a research project in which they were introduced to the futures thinking framework. They then integrated this framework into one of their science programmes as described below. These pilot studies, carried out with both primary and secondary school-aged students, suggest that the model can be used to meaningfully incorporate futures thinking into a variety of science education programmes.

## Implementing and Evaluating the Conceptual Framework

A project involving four teachers across Years 4 (8-year olds) to 12 (16-year olds) (94 students) was carried out to evaluate how the model might be used to plan and implement teaching and learning sequences in science. The three questions considered in this paper, based on a larger study (McKim et al. 2006), include:

- how suitable is the framework for a range of age groups, from middle primary to senior secondary?;
- is the language of the framework accessible to multiple age groups?; and
- can the framework be used to support a range of classroom activities?

None of the teachers had previously included futures thinking in their lessons in a manner that could be defined as structured or directed; rather, if it occurred, it was as a minor component of class discussion in which creativity and imagination were prioritised without links being made to science concepts or trend analysis. In each case, a researcher worked with the teacher as part of a professional learning programme. The goal of the

**Table 1** Possible variables to explore when using the futures thinking framework to consider future foods

| Futures thinking components | Settings | | | |
|---|---|---|---|---|
| | Personal | Local | National | Global |
| Existing situation | Nutritional needs for age and/or lifestyle | Available choices—shops, restaurants, farmers' markets | Cultural-specific preparation/ choices of foods | Concern over inequitable access to food |
| What do we eat now, and why? | Personal health | Cultural influences | Regulations relating to food availability (e.g., imports) | Nutrient deficiencies |
| | Beliefs and values—vegetarianism, kosher | | Regulations related to labelling | Retail dominance of large corporate structures (buying policies impact on food production, 'just in time' marketing determines availability) |
| | | | Need for foods to improve national health | |
| Trends | Changes in where we get our food (bought versus home grown; fresh versus pre-packaged and/or processed) | Increase in the number and variety of restaurants/take away places | Increasing choice of what is available and from where | Increased emphasis on 'convenience'—a rise in fast food outlets and ready-to-eat pre-packaged foods |
| How does what we eat now differ from what was eaten in the past? | Increased variety the choices that are available | Rise in popularity of local farmers' markets | Shop buying policies influence what is available | Concern about 'food miles' |
| Who benefits? | | | Greater availability of 'convenience foods' | Globalisation—increased exposure to foods from different countries/cultures |
| Who loses? | | | Home-grown versus bought | Fad diets promoted by celebrities |
| | | | Fresh versus pre-packaged | |
| | | | Popularity of organically grown foods | |

| | | | | |
|---|---|---|---|---|
| | | | Larger number of cooking shows on television<br>Government initiatives promoting healthier lifestyles | |
| Drivers | Family lifestyles—cost, convenience | Local deficiencies, e.g., Se | Increasing diversity—different consumer groups want different foods | Economic costs of food production and packaging |
| Are some of the changes (trends) related? | Values—beliefs about what is healthy for you | Cultural influences/beliefs of a community | Increase in food-related diseases (obesity, heart disease) | Environmental costs of food production and packaging |
| What are the underlying causes for these changes? | Awareness of personal energy and nutritional needs | Sustainability of food production and transport processes | Sustainability of food production and transport processes | Population demographics—more mouths to feed<br>Greater cultural diversity |
| Possible/probable futures | Ability to make an informed choice regarding what is purchased and eaten | Availability of specific dietary requirements in cafes and restaurants (e.g., for glucose intolerance, etc.) | Regulations affecting fast food outlets | Functional foods for specific purposes |
| Are current trends and drivers likely to persist? | Ability to afford healthy food options | | Food subsidies—e.g., no GST on fresh food/a sugar tax | Novel foods developed |
| How might they affect the future? | Individualised nutrition—foods targeted to genotype (nutrigenomics) | | Regulated control of school lunches, e.g., only healthy options available for sale | Liquids versus whole meals |
| | | | Increased role for foods traditionally used as medicine—Māori rongoa in NZ | Increased reliance on genetically modified foods<br>Ability to deliver medicine through foods |
| Preferable futures | | Students to make personal decisions | | |
| What foods do you want to be able to access? What about around the world? | | | | |

professional learning was to introduce the teachers to futures thinking using the conceptual framework outlined above, and for the teacher to work with the researcher to clarify the components of the framework and co-construct a classroom programme that would then be implemented and evaluated. As well as preliminary face-to-face meetings, there was ongoing interaction between the teachers and researchers throughout the planning, implementation, and evaluation of the classroom programmes.

A sociocultural view of learning underpinned the development of each of the classroom programmes, with consideration given to not only the social context, or culture, in which learning takes place, but also the tools that are employed (Wertsch 1991). In addition, competency was viewed as not residing in individuals alone, but as being distributed across a range of resources that include other people, cultural tools, community, as well as self (Carr 2004) and learning was participatory: new knowledge emerged in the interactions that unfolded (Hipkins 2009). The teachers had already planned to teach the following topics, into which they integrated the futures thinking framework: Dairy farming in the future (8-year olds); future foods (14-year olds); and future possibilities for genetically modified foods (16-year olds).

## Methodology and Methods

An interpretive methodology was employed to collect and analyse the data, and the findings, presented as three case studies, are descriptive and exploratory in nature. Although such studies tend to have high levels of internal validity combined with strong levels of fidelity, only 'fuzzy generalisations' are possible (Bassey 1999). The cases are therefore not offered as typical or representative; rather, they provide examples intended to enhance our understanding about what is possible.

Consistent with sociocultural approaches, participants negotiate meanings about their activity in the world (Scott and Morrison 2006). Multiple sources of data were gathered in each classroom, providing opportunities for triangulation. The data sources were negotiated in advance with each teacher and are detailed below within the case studies, but generally involved classroom observations, including researcher field notes and audio-taped recordings of teacher-student interactions; informal teacher-researcher discussions at the end of lessons; informal student-researcher discussions during the lessons; copies of teacher planning documents, teaching resources, and student work; and teacher and/or student feedback at the end of the programme, obtained through audio-recorded conversations or written questionnaires. The researchers acted throughout as participant-observers (Cohen et al. 2000), noticing classroom interactions as well as interacting with the teacher and students before, during and after the lessons.

The teacher participants were invited to reflect on the actions and interactions in their classrooms, as well as researcher interpretations. In this way they helped to construct the 'reality' with the researchers as member checkers (Robson 2002). This allowed the diverse, complex, and unique context of each classroom to be acknowledged and explored. Informed consent for the study was obtained prior to data collection from the school principals, teachers, students, and caregivers (where students were younger than 16 years of age).

From the set of detailed case studies, we highlight below aspects that relate most directly to the flexibility of the framework for its use with different age groups and different science topics; the accessibility of the framework in terms of futures language and concepts; and the opportunities provided by the framework for incorporating a range of different teaching and learning activities.

## Middle Primary

At the middle primary level, a Year 4 class (8-year olds) participated in two 50-minute 'futures' lessons at the end of a nine-week science and technology unit on dairy farming that had included an in-depth look at an automatic milking system being evaluated for use on New Zealand farms (see Biotechnology Learning Hub 2006). As such, considering possible and preferable futures for dairy farming provided a natural extension to the classroom programme. The researcher had been in the classroom as a participant-observer for the duration of the farming unit. The two futures lessons were audio-taped and the researcher chatted with students to clarify her understanding of their ideas. Copies of teacher planning documents and student work were collected and the teacher reflected on the lessons in an audio-taped post-unit interview. The focus for the futures thinking lessons is presented in Table 2.

Students participated enthusiastically in an introductory discussion about what futurists do and discussed imaginative ideas about transport and food options that might be available in the future, as well as possible features of future schools. They seemed to particularly like the use of role-play and pretending to be futurists. Their teacher commented: "Thinking about the future, inventing new things, is very powerful learning, isn't it? The kids just love it … they just go for it and it's exciting and they love it."

Students were then introduced to the five key components of the futures thinking framework, which were written on the board as five wedges of a circle. Examples from non-farming contexts (e.g., trendy clothes) were used to explain each concept. To explore trends in the dairy industry, flashcards with dates and key events over 200 years were distributed, one per student, and the class arranged themselves chronologically using the dates on each card. The subsequent discussion focused on the changes that had occurred (trends), and the implications for farmers. For example, one student pointed out that "tankers were good. The farmers didn't have to take their own milk to the factory" and another explained that being able to use a rotary milking shed "makes the job easier because you don't have to move". The trends—larger farms, more cows per farm, increased technological assistance—were then explored in terms of possible drivers: Why can farmers have more cows? Why can a farmer now milk more cows in a day than previously? What is the advantage of milking more cows per day?

Students' ideas about possible and probable futures focused on the lifestyle of the farmer (reduced manual labour because of technological advancements to assist milking; greater

**Table 2** Focus for futures thinking in the context of dairy farming, explored by a Year 4 class (8-year olds)

| | Conceptual focus |
|---|---|
| Existing situation | What is life like on dairy farms? What do farmers do each day? |
| Trends | How have dairy farms changed since the days of small herds that were all milked by hand? |
| Drivers | What has caused these changes? Why were the different inventions useful from a farmer's point of view? |
| Possible/probable futures | What might dairy farms be like in the future? What changes might occur to make the farmers' lives easier? What changes might occur to optimise the cows' milk production/health? |
| Preferable futures | Are there any things about these future dairy farms that will be better/worse for the farmer and/or the cow? Which options would you choose? |

economic advantages from being able to milk more cows) and the welfare of the cow (e.g., using video cameras in the paddocks to monitor cow behaviour and well-being). Similarly, discussion about preferable futures focused on the lifestyle of the farmer, alongside improved animal monitoring and welfare.

Students' thinking was extended and reinforced the following day with a writing activity in which small groups circulated around the class and contributed ideas in a cumulative fashion to five questions representing each of the components of the futures thinking framework:

- What is dairy farming like these days?
- How has dairy farming changed?
- Why has dairy farming changed?
- What might dairy farming be like in the future?
- What would you like dairy farming to be like in the future?

The responses, validated by informal conversations with students, suggested that the following key concepts had been considered:

- Dairy farming is labour intensive. This has implications for the lifestyle of farmers. There is also a shortage of farm workers (e.g., "Farmers do lots of work during the day"; "They milk the cows for three hours twice a day"; "Farmers have to get up at 4:30 in the morning").
- Over time, dairy farms have become bigger in size and in number of cows. Inventions such as the herringbone and rotary sheds mean that farmers can milk more cows per day. This increases profits since milk is sold by weight (e.g., "The farms are bigger. Less farmers. They invented the hearing [sic] bone shed").
- Changes in the dairy industry are driven in large part by economic and lifestyle factors —farmers want to be able to milk more cows in less time (e.g., "There has been more milk for more money so farmers got more cows").
- It is in a farmer's best interests to keep the cows healthy (e.g., future farms might have "video cameras on the farm that beep when something is wrong").
- Future changes that might make dairy farming more profitable will tend to focus on enhancing milk production in cows, and technologies involved in efficient collection and treatment of milk (e.g., "robots milking cows and checking out sick cows").

Although 'trends' and 'drivers' were not terms that the 8-year olds were initially familiar with, the teacher was comfortable with how the language had been introduced and felt that the learning would become even more powerful if the futures terms and concepts were used consistently in subsequent units: "If you did it repeatedly with all our rich tasks, if we did that type of language, they would not have trouble. They soon got the hang of a driver, didn't they?" She also believed that the futures thinking framework with its five components provided a structured scaffold students can use to explore futures concepts.

Because the futures concepts were considered at the end of the farming unit, the students were familiar with relevant scientific and technological concepts related to dairying. However, the environmental impacts of increasing cow numbers on farms (e.g., effluent run-off into waterways, and increases in methane gas production) or any political implications (e.g., the Government's commitment to reduce greenhouse gas production) were not considered. It may be that these issues were beyond the ability of the students, some of whom visited a dairy farm for the first time as part of the unit. However, including such an exploration would likely have allowed the viewpoints of a wider range of stakeholders to be introduced and considered, expanding the notion that a 'preferable future' is a personal choice, to one in which 'preferable futures' are viewed as having global implications.

## Junior Secondary

In order to explore future foods as part of a Year 10 (14-year olds) science programme, the second teacher planned and implemented a sequence of six 50-minute lessons that culminated in group presentations where students promoted the development of a future food they had designed. All six lessons were observed by a researcher and field notes were taken of classroom activities and interactions. Copies of teacher planning documents and student work were collected, the students completed an end-of-unit questionnaire, and the teacher reflected on the lessons in a post-unit interview. Table 3 presents the components of the futures thinking model explored by the class.

The first session, a whole-class brainstorm, was used to elicit students' ideas about the existing situation (what foods are currently available). Students were then required to transform this information into mind maps or fishbone diagrams and to identify trends in food over time (see Fig. 1 for an example). Ideas that emerged included:

- increased access to fast food outlets and convenience foods (e.g., 'home made' 100 years ago versus 'fast food' and 'heat & eat foods' today);
- a greater variety of foods available, including cuisine from other cultures (e.g., traditional foods such as 'haggus' (Scotland) and 'hangi' (New Zealand) versus, 'multicultural food', 'Thai', 'Indian') and greater access to meat;
- the introduction of highly processed foods (e.g., chocolate, fizzy drinks); and
- better systems to transport food nationally and globally ('home grown' versus 'exported/imported food').

A whole-class discussion facilitated by the teacher then helped the students to identify important drivers, including those related to health issues and diseases associated with poor eating habits; advertising of food products; and increased population growth and subsequent impact on food availability. Students' responses reflected an understanding of the concepts of change, the rapidity of some changes, and what change might/can/will bring.

**Table 3** Focus for futures thinking in the context of future foods, explored by a Year 10 class (14-year olds)

| | Conceptual focus |
|---|---|
| Existing situation | What types of foods are available today? Consider personal, local, national, and global perspectives. |
| Trends | In what ways have the types of foods that are available changed—locally, nationally, globally? |
| Drivers | What has shaped (driven) these changes? |
| Possible/probable futures | What foods are possible/probable in the future? |
| Preferable futures | What types of foods would we prefer to have access to in the future? Personally? Locally? Nationally? Globally? |


**Fig. 1** A Year 10 student's view of trends in eating habits and food availability

To introduce a values-based discussion about possible and probable future foods, students were presented with 15 examples (e.g., eggs with omega 3 added to reduce the risk of heart disease and arthritis, spreads with plant sterols added to reduce cholesterol levels) and asked to make judgements about the desirability of each option, that is, to place them along a continuum from least preferable to most preferable and to justify the reasons for their sequencing. The potential to genetically modify foods using modern technologies generated a lot of interest, with students asking about the process, and the teacher planned to build on this later in the year.

To develop students' ideas about possible futures, students were given a scenario situated in 2040 that required them to work in groups to design a future food and present it for funding by 'The Global Institute for Biotechnology and Foods'. A series of research questions helped focus group discussions on the underpinning science, as well as the potential benefits and risks. For example, students were asked to define the need/problem that would be addressed by their proposed future food, explain the relevant scientific techniques, and consider the potential risks and benefits of its development. Examples of student proposals included the 'hunger buster', with additional carbohydrate root storage; 'vitarice' with additional Vitamin A since deficiencies are associated with increased susceptibility to infectious diseases and vision problems; and 'yuccadas', which are "made by grafting buds of avocado onto the yucca, which has been modified to include the bamboo gene for fast growing" and combines the nutritional benefits of avocados with the tenacity of the yucca.

The work suggested that students were able to identify a need (nutritional, environmental) and propose a solution, although there was limited exploration of the scientific requirements or any potential risks. This could have been due to time constraints, the emphasis on the funding scenario (leading to a downplaying of risks), and the lack of a clear assessment guide. However, student responses to the task were very enthusiastic: "Cool—can we really design one for ourselves?" and "This is making me think", and most students (19 out of 24) indicated in an end-of-unit survey that the presentations had been the 'best part' of the unit. Students also commented that they had enjoyed "coming up with our own ideas", "working in a group", and "learning about interesting science", and only one student appeared to have been largely disengaged: "it was kinda boring cause it might not even happen". Time constraints for class activities were reported by the majority as being their least favourite part, although one student admitted that "finding the real science was hard".

The teacher helped the students to link the presentations to the overall aim of developing futures thinking skills by facilitating a whole-class discussion about factors that would shape the development of foods in the future: new technologies, such as genetic modification; outcomes of future research, such as identifying useful genes (and the sharing of this information); public support for new technologies; and needs, such as feeding a growing population. This discussion highlighted the central role of drivers in shaping technologies of the future. As such, they sit 'in the middle' and are a key component linking the existing situation with possible/preferable futures.

Although the teacher reported incorporating futures ideas into her previous teaching, she said the professional learning that was part of the research project took her "a stage further" and that the classroom programme she subsequently implemented was "highly effective in enabling futures thinking in these Year 10 students". She was particularly gratified by the level of student engagement: "It was pleasing to see the students coming in to science and being excited about what they were doing." She also liked the range of student-led activities that had been included to facilitate meaningful discussion, and reported that the futures thinking framework helpful her to develop questions to focus class discussions. In her view, positive learning outcomes included thinking that "was at a high cognitive level as they articulated and justified their positions on preferable futures", "tolerance of other peoples' viewpoints and an awareness that there are a range of views when thinking about possible and preferable futures", and an increase in students' understanding about the role of scientists in developing new foods. However, there was limited exploration of wider environmental and political issues, such as environmental sustainability of food production and transport processes, and government policies related to food safety and labelling. Trends such as eating fewer refined foods for health reasons were also largely ignored. In addition, time constraints meant that genetic modification as a process was not explored in detail, including the complexity of the genetic modification process and the potential for unforseen (and unforeseeable) side-effects (see Hipkins 2009).

Responses to the end-of-unit survey indicated that students were interested in learning more about the process of genetic modification (e.g., "What genetically engineered foods are grown now?", "How is genetic engineering/modification done?" and "Can anything be genetically modified?") as well as social, moral, and environmental aspects of genetic modification (e.g., "Is it right to allow changes that don't happen naturally?" and "What if a genetically modified plant breeds like the possums did when they came to NZ?"). The lesson sequence thus offered a powerful introduction to later science learning on the topic.

### Senior Secondary

At the senior secondary level, a single 50-minute lesson using the futures thinking framework was used by two different teachers to introduce a unit on genetics with their Year 12 classes (16-year olds) (see Conner 2010). The focus for the lessons was future possibilities for genetically modified (GM) foods. Because the students had completed a research project on GM in the previous year, they had some existing knowledge of the topic. The focus for the futures learning is presented in Table 4.

At the start of the lesson, prior knowledge was elicited through a small group brainstorming exercise in which students were required to identify GM foods as well as GM methods. Photographs of a range of commercially-grown GM foods (e.g., potatoes with virus resistance, pigs with genes for low fat) were provided as a visual stimulus and

**Table 4** Focus for futures thinking in the context of genetically modified foods, explored by two Year 12 classes (16-year olds)

| | Conceptual focus |
|---|---|
| Existing situation | What foods have been genetically modified? What processes are used to genetically modify plants or animals? How does genetic modification in a laboratory differ from traditional breeding approaches? |
| Trends | What kinds of changes/modifications to plants/animals are considered to be useful or desirable? |
| Drivers | What factors influence what gets researched and/or developed as a new food? |
| Possible/probable futures | What are we likely to see as future developments? How can we find out what is being researched, and what might be possible? |
| Preferable futures | What do we value in the types and forms of food we eat? |

students worked in small groups to identify (on a written worksheet) why the photographed examples had been genetically modified, as well as listing additional examples and identifying the reasons for the modifications. When asked to consider social, ethical, and/or environmental factors that might drive what is researched and developed, the 11 groups (from two different classes) identified on average 4.8 factors. These were mostly related to the properties of the foods: increased nutritional value, increased yield, appearance, resistance to pests, and longer shelf life. In order to consider multiple perspectives, groups were asked to list benefits and controversies associated with GM technology. Although students appeared to find this aspect difficult, discussion with the whole class highlighted that any long-term risks are largely unknown scientifically, as emphasised by environmental agencies and protest groups. Students made comments about potential genetic transfer and the risk factors associated with inserting additional genetic material such as genetic markers in order to insert the genes for a particular trait. Their concerns were grounded in their knowledge about the technological processes required for genetic enhancements and that the long term generational effects on the target organisms are not known.

The futures component was explored with students identifying characteristics of foods that might/would be desirable in the future, and the kinds of genetic modifications that would be desirable. Finally, to link probable futures with consumer demand, students were asked to consider the characteristics that they personally valued in their foods. Responses were very divergent and ranged from organically-produced foods or foods with no added artificial chemicals, to ones where taste, energy and colour were important. Students used their answers as prompts for a whole-class discussion, which subsequently became a lively debate about the use of GM. Some students argued in favour of the potential for GM to increase world food quantities and qualities, whereas others were opposed to GM although their arguments were largely emotive. Students in both classes found it challenging to consider how one would decide what the real risk of eating a particular genetically modified food is, and the scientific information they would need to effectively evaluate such risks.

Asking students to consider what kinds of foods they would like in the future harnessed their creativity and demonstrated, as one teacher commented, that 16–17 year olds are particularly interested in food. The activities also provided students with opportunities to think critically about their knowledge of molecular and conventional breeding techniques and what is actually possible in terms of gene transfer and gene expression, providing a meaningful introduction to the unit on genetics. Aspects of the worksheet, small group and whole class discussions also helped to reinforce ideas related to the nature of science, such as the tentative nature of scientific evidence as well as the limitations to our knowledge in relation to the development of new technologies. All students surveyed ($n$=42) thought the topic was relevant to them.

Whilst futures terms such as 'trends' and 'drivers' were not explicitly incorporated in the student worksheet, they provided a framework that the teachers used to develop specific questions that related directly to GM. This use of specific questions was deliberate, enabling students to focus their answers in relation to GM. The lessons also required students to discuss their ideas and prior knowledge of GM techniques in small groups, consistent with a sociocultural approach to teaching and learning. For students with more limited prior knowledge, additional resources would have helped them to understand the relevant scientific concepts as well as potential advantages and disadvantages of GM before considering the social, ethical, economic and political aspects.

## Discussion

The case studies presented above represent different ways in which four teachers used the futures thinking framework with students across a wide range of ages, from middle primary to senior secondary level. Although only exploratory in nature, they suggest that the framework provides a tool for teachers to use to plan lessons and useful prompts to help students identify dimensions of futures thinking (the existing situation, relevant trends and drivers, possible and probable futures) and select preferable futures with justification. In particular, our findings indicate that:

– students at all levels (8-year olds to 16-year olds) were able to recognise change and what it may/can/will bring;
– whilst terms such as trends and drivers may not initially be familiar, students as young as eight were able to incorporate these terms into their language and learning; and
– students at all levels were able to make value judgements about possible and preferable futures.

Both the primary teacher and the junior secondary teacher commented particularly on the high level of student engagement, and at the senior secondary level all of the students indicated in a post-lesson questionnaire that they thought the topic had been relevant. The framework therefore appeared to provide a suitable scaffold to underpin meaningful classroom programmes.

The case studies also represent three different teaching and learning contexts, suggesting futures thinking can be successfully incorporated into classroom programmes as an engaging introduction to a unit of work, a conclusion or extension of an existing unit, or as a stand-alone unit. In addition, a range of teaching and learning strategies was used to enable students to explore the components of the futures thinking framework. For example, a timeline helped the primary-aged students to identify trends and drivers in the dairy industry; brainstorming and fishbone diagrams were used by junior secondary students to analyse trends and drivers in food development, and a research project was used to develop their ideas about possible futures; at the senior secondary level, brainstorming and a worksheet with specific prompt questions provided a focus for group discussion and catered for different groups working at different speeds, and photographs of genetically modified foods provided a visual context and specific examples for the students to consider. This range of classroom activities suggests that the framework allows for flexibility in approaches, with teachers able to select activities to engage and motivate, clarify concepts, and foster values clarification and debate.

The critical role of artefacts—such as the timeline, photographs, and examples of student work that were called on in later whole-class discussions—is consistent with a sociocultural view, where artefacts are considered as being integral to and inseparable from human endeavour and functioning (Engeström 1999) that carry the intentions and norms of cognition and form part of the agency of the activity (Miettinen 2001). Having both a material and conceptual aspect (Cole 1996), they record the past and support communication of meanings and activities into the future (Wertsch 1998). Just as Roth et al. (1999) observed, the teacher-produced artefacts in our study helped to order activities in terms of topic, physical space and temporal development, with whole-class conversations about student-designed artefacts acting in a similar way although students had greater control over the direction of conversation. Negotiation of meaning was seen to involve the interaction of both participation (active involvement in discussion) and reification (through the generation of artefacts) (Wenger 1998).

Further, in order to consider future possibilities as part of their learning, students need to experience activities that challenge and extend their current understandings, and that enable them to be aware of multiple perspectives related to particular issues. Such activities also need to promote students' critical thinking skills and the ability to use, critique, and adjust their thinking through a range of discourses (Conner 2003). In our study, classroom observations suggested that establishing safe and structured learning environments gave students opportunities to learn that multiple perspectives exist and that different people may make different value judgements regarding their preferred futures. However, the complexity of interacting factors needs to be emphasised, and a broad range of views considered. For example, political and environmental issues associated with each of the classroom topics of study went largely unaddressed in the above case studies. However, the model does provide scope for these aspects, as well as issues such as health and equity, to be articulated and evaluated at the level of the individual as well as the local and global levels.

The case studies also highlight the importance of understanding relevant scientific concepts when exploring the components of the conceptual framework (the existing situation, trends, drivers, possible and probable futures, and preferable futures). For example, the primary students' exploration of future farming took place at the end of a unit on science and technology on dairy farming and students were able to draw on their experience of visiting a farm, watching the cows being milked, and talking to the farmer about his daily activities in caring for his animals and collecting and processing the milk (concepts such as cow reproduction, cow nutrition, twice-a-day milking, and herringbone and rotary sheds were all relevant). At the junior secondary level, the examples introduced to help students explore possible futures and clarify their values generated discussion about modern genetic modification technologies; a limitation of the unit was that these were not explored in greater depth, although the teacher planned to do so later in the year. At the senior secondary level, the classroom activities drew on their project work from the previous year and required students to recall specific examples of genetically modified plants and animals, as well as molecular techniques used in genetic manipulation versus conventional breeding. However, some students found it difficult to distinguish between these two techniques, and greater scaffolding may have been required by students with more limited prior knowledge.

Visioning is also important. As Ellyard (1992, p. 11) reminds us, "Humans can only work to build a future if they can first imagine it". In this, he suggests that the process of visualising ‘preferred futures’ is an essential component for working towards what is desirable. Parker (1990, p. 2) agrees:

> Visions are powerful mental images of what we want to create in the future. They reflect what we care about most, and are harmonious with our values and our sense of purpose. The tension we feel from comparing our mental image of a desired future with today’s reality is what fuels a vision.

Although Hodson’s (2003) notion of preparing for and taking action was not explored in any of the case studies presented here, the students did go a significant way towards clarifying their own views of preferred futures within their classroom topics. It is possible that the futures thinking framework has potential to scaffold the development of action competence within the domain of identifying and working towards one or more preferred futures, and this requires further exploration.

Although all of the teachers indicated that they had previously incorporated futures discussions into their classroom programmes, this had been at an informal level emphasising creativity and imagination. All four valued the opportunity to learn more about specific futures concepts, and reported that the futures thinking framework provided them with a structured scaffold to explore different factors impacting on possible and preferable futures. In particular, the framework helped students to link scientific knowledge with creative thinking so that scenario development incorporated an understanding of current trends and drivers rather than guess work or just ‘dreaming up’ what the future might look like.

## Conclusion

Futures researchers help communities to consider their preferred futures and compare those visions with current trends and scenarios of possible futures (Schultz 2003), emphasising transformational change rather than simply trend extrapolation (Burton 2005). Such thinking is increasingly regarded as a valuable approach to dealing with a world characterised by uncertainty, with the aim being to gain knowledge and understand alternatives (Slaughter 1995). In New Zealand, this is being recognised by the Government in its *Futurewatch* programme, as well as within school curriculum documents. In science education in particular, there is significant scope for including futures thinking as part of students’ exploration of socio-scientific issues. Arguments for doing so include increasing student engagement, developing students’ values discourse, fostering students’ analytical and critical thinking skills, and enhancing what the OECD has identified as ‘key competencies’. The structured development of possible scenarios within the context of a particular socio-scientific issue also offers potential for students to develop their understanding of key scientific concepts, as well as their understandings of the nature of science.

Important factors affecting futures thinking and learning include an understanding of the relevant science content; the social, political and economic factors that influence decision-making; and a recognition and evaluation of multiple perspectives. The conceptual framework presented here outlines how these might be brought together to incorporate a futures focus in science classrooms, especially where socio-scientific issues are being considered. In particular, the framework employs an inquiry methodology that uses questions to engage students in a structured exploration of scientific and/or technological issues that impact on their own and society's future. First, their 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 manner that reduces guesswork whilst still encouraging creativity. A consideration of the social context within which the changes might take place—how people respond, react, and adapt to change—is also critical, as reflected in the multiple social levels—personal, local, national, and global—built into the framework. It is intended that this will help move students' decision-making from an ego-centric activity to one valuing the welfare of the planet and all its occupants.

The classroom case studies, carried out across a range of age levels, suggest that the futures thinking framework provides a useful model to guide teaching and learning programmes, and it is our hope that it can be used to extend traditional approaches to science topics and encourage students to develop critical, reflective, and flexible responses to future-focused issues that affect them as individuals and as residents in local, national and global communities. However, it seems that teacher professional development is needed to ensure that students consider the multiple influences that contribute to socio-scientific issues. The provision of rich exemplars that teachers can emulate until they are in a sufficiently experienced position to develop their own programmes is also likely to be important. Further research is needed to evaluate the efficacy of the futures thinking framework for supporting the development of futures concepts, and to identify meaningful indicators of progression in students' learning and steps in the development of action competence.

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