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teaching and learning about controversial science issues

The overarching Nature of Science (NoS) strand in our revised science curriculum presents teachers of science with a number of challenges. One of them is the 'Participating and Contributing' achievement aim with its focus on controversial science issues (CSI). This article reports on a new classroom model for exploring controversial science issues with students that was trialled in New Zealand science classrooms, writes *Dr. Kathy Saunders*, the University of Waikato.

Introduction

Some incidents in teaching can be life-changing. A few years ago, while facilitating a meeting with local Heads of Science, I mentioned an issue that had risen locally regarding genetic engineering and suggested that this would be exciting to explore with their students. One of the Heads of Science became agitated and started to shout that this was not science and "over my dead body will I teach such rubbish!" He then left the meeting and did not return. I discussed this with the group, and it became clear, for a number of reasons, that not all teachers were feeling confident about teaching issues in their classrooms, and there were some that also did not think that it was "science" to do so. I had further informal discussions with teachers in a range of venues, and began to think that the idea of teaching CSI needed further exploration.

The recent rapid rate of scientific and technological progress has presented society with many new CSI. People, especially our students, need to be equipped with decision-making skills to enable them, as citizens, to be sufficiently scientifically literate to make well-informed decisions about problematic issues such as climate change, genetic screening, genetic engineering, cloning, alternative fuels and environmental degradation. There have been shifts in science curricula internationally, including New Zealand, towards a focus on scientific literacy. In the New Zealand Curriculum (NZC) the science essence statement asserts that students will "explore how both the natural physical world and science itself work, so that they can participate as critical, informed, and responsible citizens in a society in which science plays a significant role" (p.17). The overarching unifying Nature of Science strand of the NZC has an Achievement Aim of 'Participating and Contributing' which has a clear statement of intent regarding the teaching and learning about CSI at a number of levels. Teachers are expected to address these explicitly, but there are no guidelines on how they may be taught, or how ethical decisions are made. This has enormous implications for New Zealand science teachers.

As a result of these deliberations, I decided that it was important to establish the current status of teaching and learning about CSI in New Zealand and to explore whether some form of support might be useful to assist teachers to meet these curriculum requirements. I carried out a survey of secondary science teachers in New Zealand, followed up with interviews with some survey participants (Saunders, 2009) and it became clear that teachers needed pedagogical support to increase their confidence to address CSI in their classrooms. I then developed and trialled a teaching model to support inquiry into CSI with a small group of New Zealand secondary science teachers.

Designing the model

The first phase of the project focused around the development of a model for inquiry into CSI. The design of the model was informed by data from the New Zealand survey and interviews (Saunders, 2009) and the theoretical perspectives in the international literature based around scientific literacy, frameworks of ethical thinking, and existing approaches and teaching models for addressing CSI.

One of the main difficulties in developing a model for inquiry into CSI concerned frameworks of ethical thinking or reasoning – the area involved in how critical thinking is used to make a rational decision. Students require explicit instruction on ethical thinking, either before or during the context of the issue being studied, and this requires teachers who are also adept at applying ethical thinking frameworks.

There is no one universally-accepted framework for ethical thinking, and after examining and comparing the contributions and challenges of the established ethical frameworks – including those of Beauchamp and Childress (1993) – I decided to further develop the four frameworks presented by Reiss (2006). These are:

- *A Consequences framework*, which weighs up the benefits against the harms or risks of the consequences of an action. It promotes the common good to help everyone have a fair share of the benefits in society, a community or a family. It could be seen as 'right' to override the rights of individuals in order to bring about happiness in the wider community.
- *An Autonomy framework*, which is about making decisions for yourself, and having the right to choose. Respecting people's autonomy (independence) and decision-making abilities enables individuals to make reasoned and informed choices.
- *A Rights and Duties framework*, which defines what people can expect as their right, so far as it is under the control of people or human society. There is always a duty associated with a right, though in many cases the duty on other people is simply that they do not interfere with or prevent others claiming their rights. Any right an individual has relies on other people carrying out their duties towards that individual.
- *A Virtue or care-based ethics framework*, which acknowledges virtues valued in society such as honesty, truthfulness, courage, fairness and compassion. It is independent of any consequences of the action.

These ethical frameworks can be viewed on a short and clearly explained video introduced by Michael Reiss (2006a) on: http://www.biotechlearn.org.nz/themes/bioethics/video_clips.

Another ethical framework – Pluralism

Today's classrooms are increasingly diverse. However, none of the above frameworks consider ethical thinking in terms of multiple identities including cultural, ethnic, religious, spiritual or gender perspectives. I added a

pluralism framework to the model so that these multiple identities can be acknowledged, explored and considered in the resolving of CSI. The case is strong for New Zealand society where the Māori view is given significance by the Treaty of Waitangi which requires the Crown, as a Treaty, partner, to protect te ao Māori (the Māori world) and heed Māori advice. The incorporation of pluralism in the model enables specific acknowledgement of the cultural and spiritual differences within New Zealand society, especially Māori world views which are required to be acknowledged under the Treaty of Waitangi partnership articles.

Setting the criteria for the model

I thought it was important to establish criteria for the development of the model for ethical inquiry. The model needed to provide opportunities:

- to develop an understanding of the science concepts backgrounding the issue
- for student engagement and awareness of the issue
- for individual reflection on personal values related to the issue
- for participation in classroom discussion, conducted within agreed parameters, e.g. no winners or losers, respect for different viewpoints, no interruptions, critiquing the viewpoint not the person
- to increase awareness of how to phrase an ethical question
- to increase awareness of ethical reasoning using a range of ethical frameworks. It was important to move students away from "gut" thinking to reasoned decision making
- to use decision-making frameworks to scaffold students in organising their thoughts and justifying their decisions
- for students and teachers to reflect on their learning (metacognition) and take action if appropriate
- for teachers to use of a variety of appropriate student centred strategies and approaches to consider at various stages of the model
- for teachers to shape focus questions and prompts that could facilitate, model and encourage critical thinking in students.

Trialing, critiquing, and co-constructing the model

The second phase of the project involved the delivery of two full-day professional learning workshops, eleven weeks apart, with classroom trialling of the model between each workshop with a range of classes from Year 9-13. There were four teachers who trialled, critiqued and co-constructed the model. The final version of the trialled model is shown in Figure 1.

The model (see Figure 1) takes teachers and students through a series of coloured, sequential stages which are positioned centrally. Starting from the beginning of the inquiry process and based at the bottom of the model, the first stage is one of teacher preparation where teachers consider what they need to background their understanding of the issue, what resources would be needed, and then planning the unit to link with curriculum and school requirements. The model continues to move through a series of stages from engaging students with the issue, students backgrounding the science concepts behind the issue, individual values' exploration, group discussion of the main arguments around the issue and the ethical question(s) to be addressed. A key step in the model is the stage where students focus on ethical thinking by considering the question (or statement) from the perspectives of the five ethical thinking frameworks, before making and justifying their decision. The final stage of the model is one of reflection and metacognition which could lead to appropriate action being considered in an attempt to resolve the issue.

Sidebars are colour-coded to link with relevant stages in the model. The right-hand sidebar consists of a number of strategies and approaches that might be useful at a particular stage and the left-hand sidebar presents some question-prompts to assist in questioning, to guide the teachers in thoughtful dialogue with students and to model and encourage critical thinking.

Usefulness of the model

After the teachers had trialled and co-constructed the model, they commented on the structure of the model, the change in their knowledge base, and the students' learning.

Structure of the model

The teachers found the model to be a workable and an effective tool that improved their planning and teaching of CSI in a concrete way. They found it had flexibility depending on what they had already covered with their students, and that they could vary interpretations of stages and suggestions depending on their experience. They found that the model provided a clear focus and pathway, and that its simplicity, the colour-coding of the stages of the model, the sidebars of strategies and question-and-prompts made it easy to follow and "user-friendly". One teacher commented:

> It's a magnificent vehicle for teaching science [issues] and it's so important that we do it well because it gives relevance and meaning to a lot of stuff in today's world. (Harry)

All of the teachers believed that the inclusion of a fifth framework of pluralism was essential in New Zealand culture in order to meet the Treaty of Waitangi obligations. As one teacher commented, "Cultural perspectives are hugely important in the way people in New Zealand society view and see things." (Aimee).

Particular reference was made by all teachers to the usefulness of the strategies' sidebar. They reflected on the fact that the range of strategies encouraged and reminded them of the value of student-centred and co-operative learning strategies in providing a higher level of engagement than the teacher-centred ones they tended to use. The teachers made special mention of the value of a writing frame (see Appendix 1) as an effective scaffold to assist students to make and justify their ethical decisions. Another helpful scaffold used by some of the teachers and mentioned in the strategies' sidebar, was a computer-based bioethics thinking tool that I had developed in collaboration with other researchers at the University of Waikato for the Biotechnology Learning Hub. This can be found at: http://www.biotechlearn.org.nz/thinking_tools/ethics_thinking_tool.

Teacher knowledge

All of the teachers identified a significant change in their own learning about ethical frameworks and ethical decision making. Most reported knowing very little, if anything, about ethical thinking before the workshops. They commented on their enjoyment in the activities for learning about and using the ethical frameworks and all wanted to know more in order to develop this area of their teaching. One teacher commented:

> I really enjoyed learning about and applying the ethical frameworks myself! My own knowledge has increased. I've become quite passionate about it. I now critically listen to people's reasons for things and am better equipped to argue their reasoning. (Aimee)

The teachers identified and discussed the potential of the suggested student-centred strategies and co-operative approaches in the sidebar, not only for addressing science issues, but in the wider contexts of their science teaching. Ross mentioned how he:

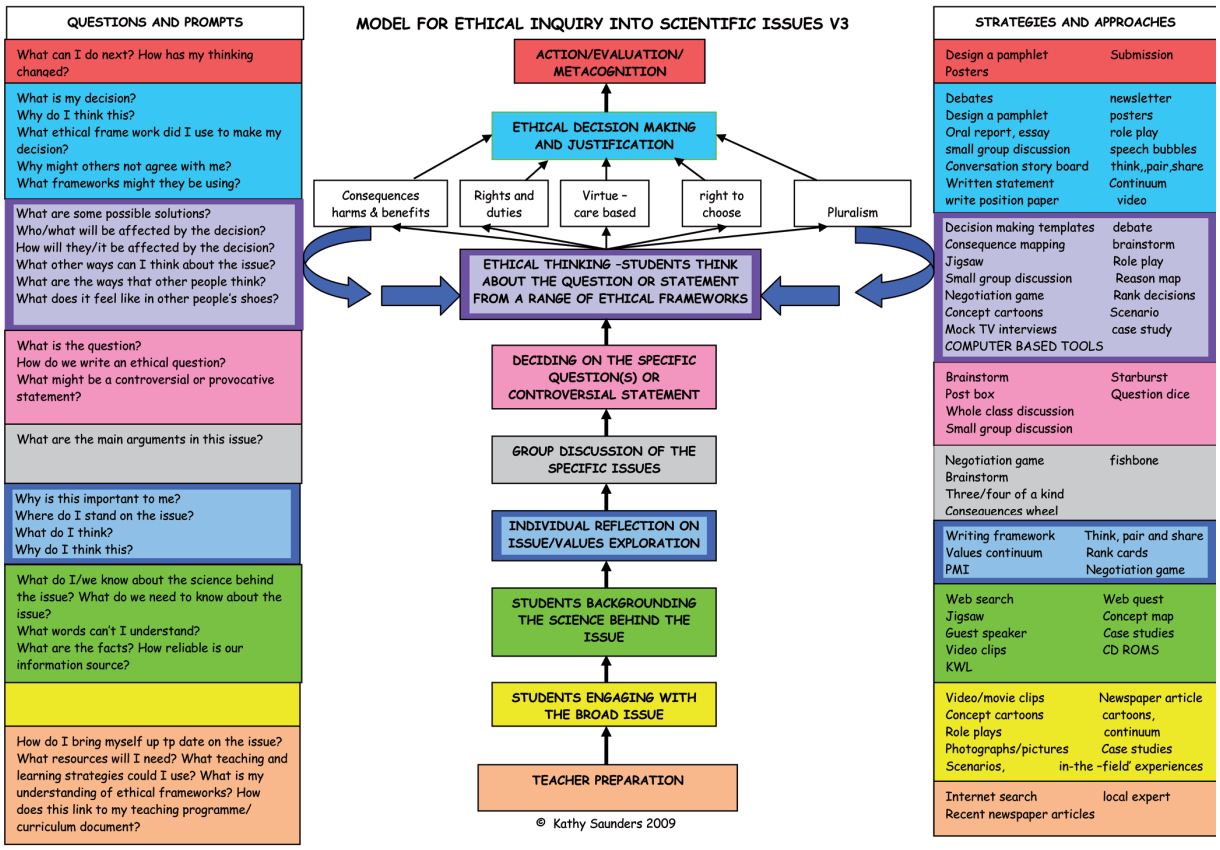

Figure 1.

> used a continuum strategy for the first time…I used approaches that I haven't used an awful lot of, but that I have used from time to time, so that was kind of exciting…thinking, 'Yeah, well actually I could try a few of these things'. You get caught in a bit of a rut…got to get through this work.

The teachers identified their understanding of the science concepts as essential to enable them to extend discussions with students. They commented that they were now more aware of resources that could help them access the background science concepts as well as tools such as video clips, computer-based tools, useful websites, and templates for scaffolding students' ethical thinking.

Student learning

In terms of students' learning the teachers commented that as a result of using the model and associated teaching and learning activities, their students had increased their science knowledge and their CSI knowledge and skills. In terms of the students' ethical reasoning, most students were able to identify the five ethical frameworks of the model, and could comment on the framework that they, or others, were arguing from. They indicated that the students were able to use a range of frameworks, with the most commonly used ones for ethical justification being those of consequentialism, autonomy and virtue ethics. Harry, commenting on his Year 13 class noted:

> They were able to provide a balanced viewpoint on key aspects of all sides of the issue and then able to develop a personal viewpoint in their conclusion. There were some exceptional arguments.

Tina also commented:

> I think the students' learning has been enhanced and challenged because this whole process has given them the opportunity to develop critical thinking.

The engagement of the students was at a high level with students "motivated and enthusiastic,""highly engaged and passionate," especially those who were not normally engaged. Tina mentioned:

> This is just a normal mid-band, Year 10 with that range of ability and the range of work-ethic...but they all seemed to be engaged – especially with some of the boys and they were able to give well thought-out reasons for their viewpoints. Engagement was high. Those students, who often do not participate in more formal lessons, took an active part in discussion.

The students reflected on their learning (metacognition) and were able to identify that they had learned about ethical decision making, and how to defend their viewpoint. One student commented on her choice of ethical framework:

> I thought about the greater good and how many benefits there would be. I also thought about being a good kind person, sympathetic to those suffering from malnutrition. (Year 9)

And another student stated:

> It was very interesting learning about the types of argumentive [sic] thinking...it triggered a critical form of thinking inside my mind. (Year 9)

In terms of social outcomes, students frequently commented that they were able to appreciate other viewpoints, and the students also made several references to their interest in other people's perspectives. They stated how it was useful to be in "other people's shoes":

> I could put myself in other people's shoes and feel how other people view the issue. (Year 12)

Unexpected learning

All of the teachers commented that they had not expected such a high level of engagement of the students, nor had they expected the students to be able to work so easily with the five ethical frameworks, including their ability to "think

in other people's shoes." Ross mentioned that he had not expected the students to be able to:

> attack the issue as opposed to the person...they were just so enthusiastic about it and getting into it and making sure that they weren't having a go at the person, but at the issue.

The teachers were unprepared for the depth of discussion and analysis which they considered "outstanding" and "thoughtful" and the confidence with which the students presented their views. Finally, they were surprised at the level of enjoyment of the students, and how some students thought that working with issues could be an interesting career.

Conclusions

The model provided clear, specific advice for teachers about a teaching sequence by:

- providing a clear pathway of progressive steps with associated strategy and questioning sidebars for teachers and learners to work through. Later with increasing confidence, teachers creatively built in feedback loops and even omitted stages
- promoting five alternative lenses through which to view ethical decision making
- promoting appropriate action as a consequence of decision making and maybe with feedback from the action recycling through the model.

Teachers using the model resulted in student learning that demonstrated:

- an increased understanding of the science concepts associated with the issue
- a high level of engagement and motivation
- an increased understanding of ethical knowledge enabling them to make and justify informed and reasoned ethical decisions
- a high level of sensitivity, respect and tolerance to the wide range of views that people hold on various issues.

The model also supported the wider intentions of the NZC by:

- supporting teachers in addressing the 'Participating and Contributing' achievement objectives of the Nature of Science strand
- enriching teachers' effective pedagogies (as required by NZC, p.34). They were more inclined to involve critical thinking, reflective thought and action, value cultural diversity and promote student-centred activities
- supporting teachers to encourage, model and explore values (NZC p.10) by giving students opportunities to express their own values, explore with sensitivity and respect the values of others, critically analyse values, negotiate solutions and make ethical decisions and act on them
- contributing to the development of key competencies as mentioned in the NZC (p.12) for example thinking about the challenging questions presented by society today as a critical and metacognitive process; relating to others by recognising different points of view, negotiating and sharing ideas; and participating and contributing with informed, active involvement in local, national and global issues
- enabling teachers to acknowledge obligations towards the Treaty of Waitangi by considering more than one world view (NZC p.9)
- working towards the vision of the NZC (p.8) for students to become critical thinkers and informed decision makers who will be confident, actively involved lifelong learners.

Overall, use of the model showed that within the small scale of this study it supported and assisted teachers to develop their confidence and pedagogical base in addressing CSI in their classrooms, to meet curriculum requirements of both the science learning area and the wider curriculum, and move towards developing their own and their students' scientific literacy.

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ask-a-scientist created by Dr. John Campbell

Is there anything colder than liquid air?

Beth Butel, Ilam School

John Campbell, a physicist at the University of Canterbury, responded.

Yes, quite a few things are colder than liquid air. Solid air is one.

Beth, we need to set up a scale to compare the temperatures of different objects. The one we use every day is the Celsius scale which is named after Anders Celsius of Sweden. On this scale water freezes to ice at 0 degrees Celsius and water boils to steam at 100 degrees Celsius.

The coldest temperature in a house is in the freezer and is about 18 degrees Celsius below zero. This is usually written as -18°C. On this scale when we cool the nitrogen gas in air it finally becomes a liquid when cooled down to -196°C.

The lowest temperature possible is minus 273 degrees Celsius. To avoid using minus numbers scientists often use another scale named after Lord Kelvin who was a famous British physicist. On this scale the absolute lowest temperature is set at zero degrees Kelvin, and the temperature at which water solidifies into ice is fixed at 273 degrees Kelvin.

This is usually written as 273K. On this scale nitrogen liquefies at 77K and the liquid becomes solid at 63K.

Only 3 light gases remain as gases below that temperature. Neon, a gas used in red neon signs and lasers, liquefies at 27K, hydrogen liquefies at 20K and the lowest temperature for a gas is helium which liquefies at just over 4K.

Scientists can use tricks to get to even lower temperatures. For example, if we pump the gas away from above liquid helium it cools to below 2K. If a man-made form of helium atoms is used (called He_3 isotope) the temperature can be reduced to 0.3K. I do this regularly to cool a very sensitive heat detector and so the lowest temperature produced in New Zealand is in my laboratory.

For further information contact:
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