The Inclusion of Bioethics Education in Biotechnology Courses

- Vaille Dawson & Peter Taylor
Science and Mathematics Education Centre
Curtin University, Perth, Western Australia
(Email: pdawsonvm@alpha2.curtin.edu.au)

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Abstract

This paper provides a rationale for the inclusion of biotechnology courses in the secondary science curriculum. In years to come our students will need to make important political, moral and social decisions about their future and the future of others. If our students are to become informed decision makers they need to understand the theory, practice and ethical ramifications of biotechnology. Important topics related to biotechnology include euthanasia, human organ and tissue transplantation, reproductive technology, cloning, and the production and use of genetically modified organisms. Science teachers have an obligation to help their students develop an understanding of these issues.

Data is presented from two science teachers, Catherine and Mark, each of whom taught innovative Year 10 Biotechnology courses (student age 16-17 years). The effectiveness of the courses in enabling students to better identify and resolve ethical issues is discussed.

What Is Biotechnology?

According to the Australian Biotechnology Association (1990) 'Biotechnology is simply the use of micro-organisms and plant and animal cells to produce food, medicine, and chemicals that are useful to mankind.'(p.1) I prefer White's (1991) term 'biological technology' which is defined as 'the whole range of technological activities involving organisms and their products and includes the biomedical technologies such as organ transplantation, life support, body parts imaging, reproduction etc.' (p.14)

Although the term 'biotechnology' is widely used within the community, a study conducted by Lock, et al. (1995) indicated that a majority of students were unable to state a correct definition. However, a short course in biotechnology increased markedly the students' understanding and acceptance of the use of biotechnology.

Why Teach Biotechnology?

As this century draws to a close, our school students face a rapidly changing and uncertain future. An explosion of advances in biotechnology including such programmes as the Human Genome project have occurred, often with scant regard for the political, moral and social implications. Indeed, there has been an exponential increase in knowledge and practical applications within the field of biotechnology. These rapid advances have led to a decreased lag time between discovery and application (Suzuki, 1990). As a result, our society needs to be able to evaluate rapidly the potential benefits and risks of biotechnological advances.

In years to come, our students will need to make important decisions about their future and the future of others. In particular, students will need to be well informed about biotechnological advances. Apart from enabling students to become informed about the practical applications of biotechnology, I believe the single most important reason for teaching this topic is to enable students to appreciate the social and bioethical implications of biotechnology so that they can become informed decision makers in the future. Some of our students will become research scientists, politicians, lawyers and business leaders, all of whom may need to make direct decisions regarding the use of technology. Yet, it is equally important that the nebulous group, often referred to as the 'general public' is also well informed so that they can be better involved in decision making (Frazer & Kornhauser, 1986). A lack of understanding by the general community of issues associated with biotechnology may lead to feelings of alienation, fear and anger towards the scientific community and their work.

Science teachers have an obligation, therefore, to help students develop the abilities to evaluate issues arising from the use of technology (White, 1991; Lock & Miles, 1993; Lock et al. 1995). A number of programmes have been developed to enable students to become aware of, and evaluate issues concerned with topics such as genetic engineering, (Armstrong &Weber, 1991; Lucassen, 1995), reproductive technology (Van Rooy, 1993; 1994), genetic diseases (Hendrix, 1993; Morris, 1994) and human organ and tissue transplantation (Transplantation: the issues, 1992; Dawson, 1996).

During the past two decades, a number of significant advances were made that had a profound effect on the use of biotechnology in agriculture, animal husbandry and medicine. The development, by the pharmaceutical company Sandoz, of the powerful anti-rejection drug, *Cyclosporin* allowed organ transplantation to become a viable alternative in the treatment of end stage renal and heart failure. (However, ethical problems related to the availability of donors, financial cost, and the use of organs from animals and anencephalic infants have yet to be resolved). Advances in molecular biology, most notably the production of restriction enzymes that would cut DNA at known sites, allowed the insertion of human genes into bacterial DNA and the subsequent cost efficient, mass production of, for example, recombinant DNA human insulin (for the treatment of diabetes), erythropoietin (to stimulate production of red blood cells in anaemic patients) and growth hormone (for use in dwarfism). An issue that arose from the mass production of growth hormone was the search for new markets by pharmaceutical companies. In the late 1980s general practitioners in America were asked to prescribe recombinant DNA growth hormone to children of short stature, despite there being no evidence of long term benefits in these children. The development of recombinant vaccines (e.g. for Hepatitis B) removed the need to use serum from infected patients. Recombinant DNA technology has also been used to insert genes into human white blood cells in the treatment of ADA (adenosine deaminase) deficiency.

Rapid and accurate DNA sequencing led to the development of genetic probes that could be used to identify whether individuals carried genes for cystic fibrosis, fragile X syndrome, haemophilia, haemachromatosis and Huntington's disease, and also to determine an individual's predisposition to diseases such as breast cancer, heart disease and Alzheimer's disease. Again, ethical issues related to confidentiality and access to information have not yet been resolved.

In the field of animal husbandry, the long term use of growth hormones in poultry and cattle to increase the growth rate and muscle/fat ratio is not yet clear. The most recent and controversial biotechnological advance in animal husbandry is the cloning of Dolly (Highfield, 1997) that is, the cloning of an animal from an adult cell. 'Dolly', a Finn Dorset sheep, was created by turning a single cell from the udder of an adult sheep into an embryo and growing it in the uterus of another sheep. Thus, Dolly is genetically identical to the female sheep from which the udder cell was taken. The lead story in our local newspaper was followed by a series of issue articles, editorials and letters to the Editor mostly related to the ethics of this type of research and the possibility of cloning humans. Most authors found the notion of cloning humans repugnant and unethical. Indeed, Ian Wilmut, Director of the Roslin Institute near Edinburgh, where 'Dolly' was cloned, stated before the House of Commons Science and Technology select committee that he found the concept of human cloning 'distressing and offensive' (''Cloning idea 'offensive,'" 1997). Nevertheless, he stated that it may be possible to clone humans within two years.

My experience with students is that while they are familiar with terms like 'cloning' and 'genetic engineering' they don't necessarily understand the scientific meaning of the terms. The term cloning means 'to make a copy'. Thus, when genes are cloned, multiple copies are made. Within the laboratory, cells have been successfully cloned in tissue culture since the 1950s. When embryos are cloned, an embryo is split and because the cells at that stage contain all of the necessary genes to develop into an individual, two identical embryos develop. What was remarkable about Dolly is that she was formed from an adult cell. Normally cells in adults are differentiated or developed. During this process, most of the genes are switched off so that the cell produces only a limited range of proteins. It is possible (although difficult) to demethylate the DNA in an adult cell so that all of the genes are switched back on. This cell is then fused with an ova that has been emptied of DNA. The cells were fused by applying an electric charge to the cell membranes of both cells. The ova (with 46 chromosomes) can then develop into an embryo. The technique is, however, fraught with difficulty and in the case of Dolly, 277 ova were used.

These examples are not meant to provide an exhaustive list of recent developments in biotechnology, nor will some readers agree that they are the most important. I realize, for example, that I have neglected entirely the whole area of

reproductive technology.

How Can Biotechnology Be Taught Effectively?

The experiences of two science teachers (Catherine and Mark) who have taught innovative Year 10 biotechnology courses at their respective schools is the focus of the second part of the paper. Major issues arising from each of the courses are identified and discussed. These issues include the effectiveness of the courses in enabling students to be aware of and critically evaluate bioethical issues, the influence of the courses on students' attitudes to science and the importance of understanding the procedures involved with biotechnology. The teachers have allowed me to use their first names, although the names of the schools are not used and all students names have been changed to ensure their anonymity.

Case Study Research Methodology

The research methodology undertaken in this study is based on an interpretive case study (Merriam, 1988, p.27). Utilizing Guba & Lincoln's (1989) *credibility* criteria for judging the quality of this type of qualitative research, the extent to which the teachers' and students' experiences were honestly portrayed was enhanced through prolonged observations and frequent feedback to the teachers at all stages of the data collection.

Sources of data include classroom observations, multiple teacher and student interviews, questionnaires related to students' perceptions of the courses and my own reflections recorded in a personal journal. After each teacher interview and classroom observation, I wrote up and gave the teachers my written records to act as a 'member check' and to stimulate discussion in subsequent interviews.

It is beyond the scope of this paper to discuss all of the issues that arose during the case studies. Thus, in each case, I have chosen to focus on the two most important goals raised by the teachers themselves during initial interviews.

Catherine

Catherine, teaches in an independent girls school in Perth, Western Australia and is in her second year of teaching. She did her initial degree in Microbiology and then worked in a Virology laboratory until she had children. She spent ten years at home before choosing teaching as a career as it allowed her to care for her now school aged children. As a teacher, I would describe Catherine as caring, very organized, controlled and logical. She is fairly strict with her classes.

The two pedagogical goals that seemed most important to Catherine were, firstly, whether the course enabled students to be aware of and critically evaluate bioethical issues in science and, secondly, the effect of the course on students' attitudes to science. Catherine believed that it was important 'that students can take a moral stand on issues and that they know how to make decisions about bioethical issues'. (Interview, 18/7/96).

During 1996, the Year 10 science curriculum at the school was modified to provide a choice of courses to cater for the variable interests and ability levels of students. Two major changes were the introduction of a Forensic Science course and a Biotechnology course. At the end of Year 9, students chose 5 topics (each of six weeks duration) from a choice of 7. The two new courses offered an option for those students who did not intend to study physics and chemistry in Years 11 and 12. Within the Biotechnology class of 30 were students with a range of abilities. When asked by Catherine (and myself during student interviews) why they had chosen the course, their reasons included: an alternative to physics and chemistry, subjects which they perceived they had neither the ability or interest to succeed in; an interest or intention to study human biology in Years 11 and 12 or pursue a career in a related field, and a belief that the course would assist their later studies; and, finally, an interest in a new topic offered by the school.

The Biotechnology course was based on bioethical issues associated with human organ and tissue transplantation. Bioethics can be defined as the study of ethical issues associated with the use of living organisms and medicine. It includes both medical ethics and environmental ethics. Rather than defining a correct decision, it is about the process of decision making, balancing different benefits, risks and duties (Macer, 1994).. Bioethics education is about helping students to develop, articulate and critically evaluate their own bioethical values and become aware of the multiplicity

of values that exist in our society.

The primary resource used by Catherine was the Transplantation kit developed jointly by the Australian Kidney Foundation and the Science Teachers Association of Victoria (Transplantation: the issues, 1992). Some of the teaching strategies used by Catherine included discussion of case studies that raised ethical dilemmas, role plays, design and administration of a questionnaire to determine the views of friends and relatives toward transplantation and preparation of a library portfolio. The portfolio required students to collect and comment critically on media articles related to a controversial issue.

Students' awareness and ability to critically evaluate ethical issues in science

During the first lesson, Catherine chose to discuss the movie, 'Junior'. In the movie, the main character, played by Arnold Swarznegger, steals a frozen ova which is fertilized and implanted in his peritoneal cavity. She believed that the movie raised many ethical issues and would encourage students to think about them. She found that although students had seen the movie they were unaware that there were any ethical problems. In an early interview she explains: "For me, the taking of the egg was unbelievably wrong, whereas for most of the students they just accepted it. The big issue was interfering with nature. In Junior, the man is having a baby. Is this right? I asked them. Do you want to give up your unique role? They hadn't though about it. In fact after seeing their lack of reaction, one of my objectives in this unit is to make them aware of the implications of what they read or see instead of just accepting everything at face value. I kept saying, well what do you think? They just looked at me." (Teacher interview 25/7/96)

Thus, early in the teaching of the course, Catherine chose deliberately to increase students awareness of ethical issues.

Catherine informed me that she introduced students to a decision making process to resolve ethical dilemmas. That is, the students identify a range of options, weigh up the risks and benefits of each and then select an option. It was not necessary (nor desirable) that all students arrive at the same answer. Catherine also taught students about the bioethical principles of autonomy, justice and non-maleficence. She used the example of abortion to demonstrate that there will often be conflicting rights.

Almost every lesson, Catherine raised ethical issues and challenged the students to articulate and reflect on their views in whole class or group discussions. By the end of the course, Catherine felt that the students had made progress in being able to critically reflect on ethical dilemmas. In a later interview she said: "I guess I feel intuitively there has been a change. When I did that first exercise on the movie, Junior, I went through all the issues and they didn't think any of them were issues. Now, they are more curious and ask more questions." (Teacher interview, 13/8/96)

My impression from observing Catherine's class is that the students were asking more questions of themselves and their peers and generally trying to grapple with issues. At the end of the course, I asked Catherine what she thought the students had learnt. Catherine comments that: "The kids got a lot out of it. It has opened their eyes to the fact that they do have to think. I said to them that I hope when they read articles that they don't just accept what's written, that they do stop and think; where is this leading us? do we want to do this? what are the issues involved?" (Teacher interview, 2/9/96)

During the second interview with the students (31/7/96), it seemed that they were aware that a consideration of ethical issues was one of the course objectives. When asked what they were meant to learn in the course, Sarah replied 'about social issues, about what society accepts and to find out other peoples points of view'. When I asked the students how they would decide what to do if they faced a dilemma, Holly said, 'I'd look at the advantages and disadvantages and weigh them up. At the conclusion of the course, Sarah stated that the course 'hadn't changed her views, but it has helped me to know the reasons for my views and to understand what other people think.'

Catherine's perceptions regarding increased student awareness of ethical issues are supported by students' questionnaire responses. When asked to state the three most important things they had learnt, the students' comments included, 'there are many issues in our society that are hard to find the right answer to', 'everyone has different opinions and we should respect their views', 'I learnt to think more about social issues and other peoples views', 'what my ideas on ethics are'.

Students' attitude to science

Catherine has a positive attitude to science, an attitude she wanted to pass onto her students. She worked hard to ensure her students succeeded. Indeed one of her main goals as a science teacher is to: "make it as interesting as possible. Some students have a negative attitude to science. I want to get their attention,. I want them to see that if they listen, work and try, then they will achieve in science. I do this by being extremely organized, by presenting information clearly and sequentially. I understand that students learn in different ways. I also include students in the lesson. I make sure that every lesson, each student answers at least one question." (Teacher Interview, 18/7/96)

My classroom observations indicated a high level of interest regarding the topic of transplantation and enthusiasm towards the various activities. Catherine was always well prepared and able to answer students' questions. Indeed one students wrote that 'Mrs. M knows what she is talking about and can tell us things without looking through notes all the time. She got us involved and expressing our opinion. It was very interactive.' During the final student interview, I asked students how they would rank the course compared to their previous experience in science.

Me: If you looked at the unit as a whole and you compared it to other science units you have done. And you gave those units a ranking of five, how would you rate this unit? Melanie?

Melanie: A nine. I think it's a lot better than the other ones. It's so much more interesting. Not just facts. It's more worldly.

Me: Sandra?

Sandra: Probably about 8.5. All the other ones were really boring until I got to this one. I've never enjoyed science.

Me: You've never enjoyed science before?

Sandra: No. I've never enjoyed science. Until I did this unit. Now I'm going to do human biology next year.

Christina: I would give it a 10 because I really liked it and I haven't been bored. It's good. I know you can be wrong but most of it is your decision and as long as you can explain your decision it's OK.

Jacinta: I would give it about 9.5. I agree with what everyone else says. As long as you can back up your opinions it's OK.

Me: Well that's good. Really positive. What about other students in the class? Do they think the same?

Christina: I think so. They all contribute to the discussions.

Melanie: And most people are getting high marks. Higher than what they usually do.

Written comments from the questionnaires supported the perceptions of these students. Comments included:

'I used to hate science, but I understand biotechnology because there is lots of discussion. It suited my style of learning.'

'Before I thought science was hard and irrelevant. I used to dread a double period in science or any science period because I was afraid of having to answer questions, but now I look forward to it.'

'It has persuaded me to take up human biology in Year 11 and 12. I never knew this stuff was part of science and it has been the best one yet.'

'Science doesn't have to be about chemistry and physics, but about everyday problems.'

Mark

Mark is a biology teacher at an independent boys school in Perth, Western Australia. A Biotechnology course,

developed in part by Mark, has been taught at the school since 1990. It comprises three sections; 'Enzymes in Industry', 'Plant Tissue Culture' and 'Recombinant DNA'. The recombinant DNA technology section exposes students to the theory, practice and ethical ramifications of genetic engineering and cloning.

Mark has always been interested in biology and it was his favourite subject at high school. He initially enrolled in biomedical science and although he was enthusiastic about the content of the course, his future job prospects were uncertain. Thus, at the end of his first year he transferred to a Bachelor of Education course majoring in biological science. He was familiar with the demands of teaching as a profession because both his parents were teachers. He initially taught in the state school system for five and a half years before obtaining a job at his present school in 1990. Mark is currently acting Head of Biological Science.

The biotechnology course was developed by the previous Head of Biological Science who obtained a Fellowship to travel to America to obtain information about existing biotechnology courses, especially those related to DNA technology. The science department then obtained a grant which enabled them to buy the initial (expensive) equipment and reagents to set up the course. The science department was committed to changing the Year 10 science curriculum and all Year 10 students study the course rather than the more traditional genetics and ecology courses offered in most schools. Mark did not believe that the students were disadvantaged in Years 11 and 12 when they needed to study these topics in biology or human biology. Indeed, the number of upper school biology classes has increased from two to four since the introduction of the course.

Although the course covers three areas of biotechnology; plant tissue culture, enzymes and recombinant DNA technology, my classroom observations, teacher and student interviews and questionnaires focused on the recombinant DNA technology section. Students are provided with a booklet that contains theory, practical work and work sheets. Firstly, students are introduced to cell theory, cell microstructure, the nucleus and chromosomes. They then examine the double helix structure of DNA and the genetic code. During the next lesson, students isolate DNA from onion cells. DNA prepared in this way looks like thick, white saliva. Students then prepare a gel that can be used to separate broken pieces of DNA. The DNA is broken up with special enzymes called restriction enzymes. This process of separating the fragments of DNA, known as electrophoresis, involves passing an electric current through the DNA in the gel. DNA is negatively charged and will move towards the positive electrode. The smaller the piece of DNA, the faster it will move. The pieces of DNA can then be visualized by staining the gel with a dye such as methylene blue. The DNA stains intensely.

Increasing students' awareness of ethical issues

Mark's main goals in teaching the recombinant DNA section of the unit appeared to be, like Catherine, to increase students' awareness of ethical issues in science and also to increase the students' knowledge of the terminology and procedures used in DNA technology. He stated that 'the more informed the students are, the more likely it is that they will become well-informed community members'.

During our initial interview, Mark showed me some of the newspaper articles and videos that he used to stimulate discussion about ethical issues in class. He encouraged students to ask questions and express their opinion. He has used videos from a BBC series (narrated by David Suzuki) that includes 'Cracking the Code' and 'Designer Babies'. Mark believes that using the media as a source of information is more 'real life' than using text books. In the past, they have discussed the human genome project (where every human gene is to be mapped) and the potential ramifications for employment and life insurance; for example, if you carry a gene that predisposes you to cancer, should you be given life insurance with the same premiums as someone who does not have the gene? He also encourages students to bring in articles of interest (to them) and explains that he will forego his lesson plan to allow the students time for discussion. He wants his students to acquire the skills to understand new technology so that they can be informed decision makers when they become adults.

One of the activities that Mark conducted with his class was specifically designed to encourage the students to consider the ethical issues associated with the cloning of Dolly. Prior to this lesson, students had discussed the meaning of the word 'ethics'. Mark used their responses and his own beliefs to construct a working definition. Mark asked the students 'what kinds of questions can we ask to decide whether we are acting ethically?' Their questions included the following.

What is the purpose of this procedure? What are the advantages and disadvantages in the short and long term? Is it right to interfere with Nature? Is there a risk to the environment with this procedure? Who should control the rights to the technique? Is this research offensive to any community groups? I was impressed by the students' questions. The students' questions demonstrated that they were thinking carefully about the effect of biotechnology on society. By requiring students to pose the questions, they needed to think about how they would decide whether an action was ethical or not.

During the next lesson the students had the opportunity to apply their questions to the issue of the cloning of Dolly. Mark had prepared a handout listing their questions and an article related to the cloning of Dolly, a topic that had generated a great deal of student interest in previous lessons. He asked students to work in small groups and to choose the six most relevant questions. The students were then asked to attempt to answer them. Finally, they needed to state their opinion regarding the cloning of Dolly. Most students agreed that more information was needed before they could decide whether the procedure was right or wrong. They also suggested that the newspapers were not necessarily an appropriate source of information. Mark suggested that they read scientific journals.

Questionnaire responses indicated that more than 50% of the students thought that an increased understanding of ethical issues related to DNA technology was one of the most important goals of the course. The opportunity for group and class discussions, in addition to their teacher's understanding of the topic, helped to increase their awareness of issues.

Importance of content knowledge

Before students were exposed to the ethics section of the course, they covered the theory and practice of DNA technology. Mark believed that it was essential that students understood the technology if they were to make informed decisions about associated ethical issues. When interviewed, Joshua stated that because he was now familiar with the technology, he was much better able to state his opinion. He believed that because he had actually isolated and electrophoresed the DNA, he had more insight than if he just read about the cloning of Dolly, for example, in the newspaper. He stated that scientists and others who do these types of experiments should obtain permission from a tribunal or committee before embarking on controversial experiments. When I asked him who should be on the tribunal he asserted that it should include geneticists, other scientists, human rights representatives, and members of religious organizations so that an overall view could be obtained. Another student stated, during an interview, that although understanding the technology did not necessarily change his views, he now felt that his view was more valid.

Conclusion

In summary, both Catherine and Mark believed that an essential component of their biotechnology courses was to increase their students' awareness of ethical issues and provide them with opportunities to articulate and clarify their own views as well as appreciate the views of others. Catherine and Mark explicitly presented students with ethical issues related to the course content. Both teachers used small group and whole class discussion, throughout the course, to encourage students to reflect on their beliefs. They wanted their students to develop their own bioethical values. Catherine and Mark commented, during interviews, that by teaching the courses, they had also increased their own understanding about the use of technology and confronted and evaluated their own ethical values. Catherine, who was enthusiastic about science and technology, also provided a range of activities which helped students develop a more positive attitude toward science.

Finally, it would appear that when dealing with complex issues such as cloning and genetic engineering, it is impossible to discuss or resolve ethical issues in a meaningful way without an in depth understanding of the processes involved. It is highly likely that, within the next decade, our society will need to consider the ethics of cloning humans. Unless all students are taught about the process of biotechnology they are in danger of being woefully ignorant about the technology involved. This lack of understanding and associated fear may contribute to an anti-science backlash where society rejects rather than confronts the ethical issues.

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