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An Exploration of High School (12–17 Year Old) Students' Understandings of, and Attitudes Towards Biotechnology Processes

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Abstract The products of modern biotechnology processes such as genetic engineering, DNA testing and cloning will increasingly impact on society. It is essential that young people have a well-developed scientific understanding of biotechnology and associated processes so that they are able to contribute to public debate and make informed personal decisions. The aim of this study was to examine the development of understandings and attitudes about biotechnology processes as students progress through high school. In a cross-sectional case study, data was obtained from student interviews and written surveys of students aged 12 to 17 years. The results indicate that students' ability to provide a generally accepted definition and examples of biotechnology, cloning and genetically modified foods was relatively poor amongst 12–13 year old students but improved in older students. Most students approved of the use of biotechnology processes involving micro-organisms, plants and humans and disapproved of the use of animals. Overall, 12–13 year old students' attitudes were less favourable than older students regardless of the context. An awareness of the development and range of students' understandings and attitudes may lead to a more appropriate use of biotechnology curriculum materials and thus improved biotechnology education in schools.

Key words biotechnology education · gene technology · public understanding of science · scientific literacy

Introduction

One of the essential outcomes of science education is to enable students to develop a deeper understanding of the world around them, and to be able to engage in

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relevant discourse about science in everyday life. In Australia, there has been a significant emphasis placed on the importance of scientific literacy in science education (Goodrum, Hackling, & Rennie, 2001). All Australian State and Territory curriculum documents state that science education should aim to develop students' scientific understanding, problem solving and critical thinking skills related to science topics of importance in society. A high level of scientific literacy can help young people to question the claims of the scientific community, weigh up evidence about science issues, use critical thinking skills and enable them to use their understanding of science to make informed and balanced decisions. One area of science that will increasingly impact on our society is the field of biotechnology. There is a sense of disquiet amongst people in many countries about the use of uses of cloning and gene technology. It is important that the community is well informed about the practical applications of biotechnology, especially those applications related to human health, forensics, agriculture and the environment. Education in schools about biotechnology issues can help to ensure that young people have the knowledge and skills to enable them to contribute to public debate and make informed decisions.

Understanding of Biotechnology

There is little published research data on Australian high school students' understandings and attitudes about biotechnology processes. This is partly because Australian research on understandings and attitudes about biotechnology tends to focus on the views of 'adults as consumers.' However, in a recent study, 1,116 year 11 (15–16 year old) students from 11 Western Australian schools were surveyed to determine their understanding of recent advances in modern biotechnology (Dawson & Schibeci, 2003a). Year 11 students were selected as the target group because they have completed their 10 years of compulsory schooling and for those who continue their high school education, science is not a compulsory subject. The results indicated that most students have little or no scientific understanding of biotechnology, genetic engineering, cloning, or genetically modified (GM) foods. Many students were unable to distinguish between current and potential uses of biotechnology. For example, some students stated that organs, limbs and humans are currently cloned. The responses given as examples of biotechnology seemed to indicate that students confused biotechnology with other new technologies (e.g., reproductive technology). Some students were also confused about the difference between cloning and genetic engineering, believing that Dolly the sheep was genetically engineered. Most students were unable to distinguish between GM foods and foods produced through selective breeding. These findings are comparable with similar studies in the United Kingdom which suggest that many high school students do not understand the processes of modern biotechnology (e.g., Chen & Raffan, 1999; Gunter, Kinderlerer, & Beyleveld, 1998).

Attitudes to Biotechnology

The term, 'attitude' is used in this paper, and by other authors (e.g., Bredahl, 2001; Chen & Raffan, 1999) to indicate whether a person approves or disapproves of a particular biotechnology process. Although the authors refer to both positive and negative attitudes in relation to biotechnology processes we do not wish to imply that positive is ‘good’ and negative is ‘bad.’ Rather, the terms are relative in this study and a positive attitude is displayed by students who state that they approve of a wider range of biotechnology processes than other students. Attitudes are important because a person’s intention, subsequent behaviour and decisions are affected by both their attitude and their perception of society’s values about issues (Ajzen & Fishbein, 1980). In an extension of their examination of understanding, Dawson and Schibeci (2003b) surveyed students about their attitudes towards a range of biotechnology processes that involved the use of micro-organisms, plants, animals and humans. The students held a wide range of attitudes about what is an acceptable biotechnology process. Most students (>90%) approved of the use of micro-organisms for specific biotechnology processes such as producing beer. There was less support for genetic modification of plants (71%–82%), and even less for the use of animals (34%–39%) or humans (41%–45%). Again, these findings are comparable to UK school students who tend to display a more positive attitude to genetic modification of micro-organisms and plants than genetic modification of food crops, animals and humans (Gunter et al., 1998).

Relationship Between Understanding and Attitude

Research findings on the relationship between scientific understanding and attitude to biotechnology are ambiguous, with results depending on the sample construction, data collection methods and the way that understanding is determined. Both Bredahl (2001) and Wohl (1998) conducted large surveys of European adults and found no relationship between scientific understanding and attitude towards GM foods, although both strong positive and negative attitudes were held in the absence of understanding. The *Eurobarometer 55.2* (European Commission, 2001) survey results from over 16,000 Europeans over the age of 15 found that although participants’ attitudes to science and technology are generally more favourable with increased knowledge, this was not the case with genetically modified organisms. Although there was less uncertainty, some respondents with high levels of knowledge believed that genetically modified organisms would harm the environment. The negative attitude to genetically modified organisms is also reported in *Eurobarometer 58.0* (Gaskell, Allum, & Stares, 2003). However, attitudes to genetic testing for genetic diseases and cloning are more positive amongst those who have a greater understanding of biotechnology. Gamble (2002) in a study of New Zealand adults found a weak positive correlation between actual knowledge and acceptance of genetic modification.

Within high school contexts, there are conflicting findings on whether an increased understanding of biotechnology influences students’ attitudes. Lock, Miles and Hughes (1995) found that after 16-year-old students in the UK were taught about biotechnology and genetic engineering (two lessons) their knowledge increased, attitudes became more favourable towards biotechnology and there was less uncertainty about their attitudes. Taiwanese and UK students studying A level Biology in Chen and Raffan’s (1999) study had more favourable attitudes toward biotechnology and genetic engineering that those not studying biology. Hill, Stanistreet, Boyes, and O’Sullivan (1998) also found that biology students were less likely to be neutral and more likely to be positive about genetically engineered foods than those not studying biology. In the US, Sadler and Zeidler (2005) examined the influence of genetics content knowledge on informal reasoning about genetic engineering issues with undergraduate natural and non-natural science students. They found that "differences in content knowledge were related to variations in informal reasoning quality" (p. 71) and that students with better content knowledge used this knowledge to explain and support their viewpoint. The students with better content knowledge were less likely to present flawed arguments.

In contrast, Olsher and Dreyful (1999) reported on a study of 105 year 9 (15 years old) students who were taught about genetics and biotechnology. The students completed an attitude questionnaire which was based on the students role playing a committee member who had to decide whether to permit the use of a genetically engineered hormone to increase milk production in cows. When the results of these students were compared to those of a control group there were no differences in attitudes. However, the experimental group did propose more arguments for and against the technology, indicating a greater awareness of the issues. In another study (Dawson, 2003), 120 14–15 year old students from three schools completed a six lesson module on DNA structure and DNA testing for paterntity. The students' understanding of DNA testing and their ability to resolve and justify an ethical dilemma about forensic DNA testing was examined. Using a pretest/posttest survey and interviews, the results indicated that after completing the module, the students' decisions did not change. However, students were more likely to use their increased scientific understanding of forensic DNA testing to justify their decisions. Similarly, Zohar and Nemet (2002) found that after year 9 (15 year old) students were taught the topic of genetics and explicit argumentation skills that they used their biological knowledge to improve the quality of their arguments about bioethical dilemmas.

Upper secondary school courses in biological science now have an increasing emphasis on genetics, gene technology, cell biology and cloning. Before science teachers are able to engage students to increase their understanding of these concepts, it is necessary for them to be aware of the students' prior knowledge. A constructivist approach to teaching and learning recognises the importance of establishing the ideas and knowledge of students. These prior conceptions can provide a foundation for teachers to build on or alternatively they can impede learning (Tytler, 2005). Although a number of recent studies (Lewis & Kattmann, 2004; Venville, Gribble, & Donovan, 2005) have examined the development of school students' understandings of the concept of the gene, as far as the authors are aware there is no published research about changes in high school students' understandings of biotechnology processes. The aim of this preliminary research study was to determine how understandings and attitudes about biotechnology change as students progress through high school. The study addresses the research question; what are high school students' understandings of, and attitudes towards a range of biotechnology processes? The study focuses particularly on the areas of gene technology, cloning and GM foods because they are areas about which there is significant debate internationally regarding their current and potential uses.

It is appropriate to define the terms, 'biotechnology,' 'genetic engineering,' 'cloning' and 'genetically modified (GM) foods' as they are used throughout this paper. Biotechnology includes those biologically based technologies which humans use to yield products of various kinds. Thus 'biotechnology' includes:

- technologies involving bread- and wine-making which have been used for thousands of years;
- cell biology applications such as tissue culture and cloning; and
- genetic engineering.

Genetic engineering involves taking genes from their normal location in one cell and either transferring them elsewhere or placing them back into the original cell in different combinations so that the cells are capable of producing new substances or performing new functions. Cloning of cells (e.g., stem cells) results in genetically identical cells. Cloning to produce a genetically identical organism (as in Dolly the sheep and others) is genetic transfer of the whole genome which occurs when the nucleus of an adult cell is placed in an ovum which is then fertilised. The deoxyribonucleic acid (DNA) in GM foods has been deliberately altered in some way by, for example, removing or adding extra copies of a gene or adding genes from a different organism. A GM food may contain modified DNA and/or the modified protein.

Research Method

The research design and methods are developed within a qualitative research paradigm. Data generation and analysis is informed by a constructivist conceptual framework (Denzin & Lincoln, 1998). An instrumental case study approach (Stake, 2000) is the primary research method used in this study. A case study is an examination of a specific topic; in this case, students' understandings of, and attitudes towards biotechnology processes at a metropolitan high school in Perth, Western Australia. It is intended that the findings of this case study, which is exploratory and cross-sectional, will inform the design of further research to examine high school students' understandings and attitudes about biotechnology and subsequently improve biotechnology education. Using this case study approach, data was generated through semi-structured student interviews and written student surveys. The use of these multiple sources of data allows triangulation and cross-checking of emergent hypotheses.

Sample

Towards the end of the school year in November, 2003, a total of 465 students in years 8 (12–13 year olds) (n = 175), 10 (14–15 year olds) (n = 175) and 12 (16–17 year olds) (n = 115) completed a written survey about their understandings of, and attitudes towards a range of biotechnology processes. The students attended a large, inner suburban, co-educational government high school. The students at this school can be described as 'culturally diverse' due to the relatively high proportion of new migrants from Europe and South East Asia in the school catchment area and also the offering of language scholarships in Italian, German, and Indonesian to students outside the local area.

At this school, science is compulsory in years 8, and 10. Science is timetabled for 4×60 min lessons per week over the 40-week school year. Each year, students study topics in physics, chemistry, biology and earth sciences. In year 8, students are introduced to the concepts of life and cells in their biology topic. Students are taught how living organisms differ from non-living organisms. They use simple microscopy to compare plant and animal cells and are introduced to cell structure and function. In year 9, the biology topic introduces students to the interaction of living organisms and abiotic factors in ecosystems and to the structure and function of body systems. In year 10, students are split into two groups based on ability with the higher ability students studying more rigorous chemistry and physics topics. All of the year 10 cohort studies the same biology topic of reproduction, inheritance and Mendelian genetics over a 10-week school term. In this topic, students were also introduced to genetic diseases, *in vitro* fertilisation and cloning (of Dolly the sheep). In years 11 and 12, students can elect to either discontinue with science or to study chemistry, physics, biology, human biology or an integrated science subject. The year 12 students in this study who have studied biological science for the past two years will have covered genetic diseases (inheritance, symptoms, diagnosis and treatment), DNA structure and function, and protein synthesis.

Data Sources

The written survey was administered to students in two separate sections (understanding and attitude). The understanding section allowed open-ended responses and was a modified version of that used in an earlier study to determine adolescents' understandings of, and attitudes towards biotechnology (Dawson & Schibeci, 2003a, 2003b). Students were asked to define and give examples of areas where biotechnology and cloning are currently used in our society and to define and give examples of genetically modified foods currently available in Australia. The students had unlimited time to complete the survey although all students completed the survey within a 20-min time period. They were reassured that it was not a test and that questions could be left blank. The surveys were anonymous to encourage an honest response. Students indicated their year group and year 12 students stated whether or not they were studying biological science.

When the understanding section was submitted, students were given the attitude section. To determine attitudes, participants read through a list of 15 biotechnology processes ranked from benign uses such as *Using yeast in the production of wine and beer* to more controversial procedures such as *Inserting genes from humans into the fertilised eggs of mammals* (see Figure 1 for a complete list). Students indicated whether or not they found each of the statements acceptable. All survey responses were coded and analysed statistically. Results for understandings and attitudes of each year group were compared.

In addition, six students from each year group were interviewed in two groups of three about their understandings of, and attitudes towards biotechnology, cloning of endangered species and humans, genetic testing for diseases, paternity, forensics, and genetically modified foods. Students were also asked where they had learnt about these topics as it had been previously reported that amongst teenagers in the UK, TV news and documentaries are the most frequent sources of information about biotechnology (Gunter et al., 1998). Students were selected by their teachers

No	Statements	Type of organism
1	Using yeast in the production of wine and beer	microbe
2	Growing yeast for animal food	microbe
3	Using genetically engineered micro-organisms to enable more efficient breaking down of human sewerage	microbe
4	Altering the genes of plants so that they will grow better in salty soils	plants
5	Adding genes to yeast that is then used to make better tasting bread	plants
6	Adding genes to plants to increase their nutritional value	plants
7	Altering genes in fruit to improve taste	plants
8	Altering genes in tomatoes to make them ripen more slowly and have a longer shelf life	plants
9	Inserting genes from micro-organisms into crops to provide pesticide resistance	plants
10	Changing the genetic makeup of farm animals to improve the quality of meat and milk	animals
11	Using genetically engineered cows to produce medicines for human use	animals
12	Inserting genes from plants into animals	animals
13	Altering the genes of human tissue cells to treat a genetic diseases (e.g., cystic fibrosis)	humans
14	Altering the genes in an embryo to treat a genetic disease	humans
15	Inserting genes from humans into the fertilised eggs of mammals	animals

Figure 1 Statements about biotechnology processes

using a purposeful sampling method (Patton, 1990) that allowed for maximum variation so as to perceive a wide range of students' views. The semi-structured interviews were audio-taped and transcribed. The transcripts were analysed separately by each author for emergent themes. The biology teacher, who had taught at the school for 14 years, was also interviewed about the biological science aspects of the science curriculum.

Results

Understanding of Biotechnology Processes

The percentage of surveyed students from years 8, 10 and 12 who provided a generally accepted definition or provided correct examples of biotechnology, cloning and GM foods is summarised in Table 1. Year 12 students are divided into two groups based on whether or not they were studying a biological science subject. Biotechnology was defined as the use of "*living organisms* to produce useful products," cloning as "making a *genetically* identical copy" and a GM food as "a food where the *DNA* had been changed."

The results (Table 1) indicate there was an improvement from year 8 to 10 to 12 in the students' ability to define and provide examples of biotechnology, cloning and GM foods. Year 12 students studying biological science had the best understanding of biotechnology, cloning and GM foods while the non-biological science year 12 students did not differ from the year 10 group. Biotechnology was the least understood term with only one year 8 student (out of 175) able to provide a generally accepted definition. Most of the year 8 students (84%) left the question blank or wrote "I don't know." This relatively poor understanding was reflected in the student interviews where none of the year 8 students could provide a correct answer. Four of the six year 8 students could not answer the question, "what is

Table 1 Percentage of Year 8, 10 and 12 Students Who Gave Generally Accepted Definitions or Examples of Biotechnology, Cloning and GM Foods.

	Percentage of year 8 students (n = 175)	Percentage of year 10 students (n = 175)	Percentage of year 12 students (no biological science) (n = 35)	Percentage of year 12s (biological science) (n = 80)
Definition of biotechnology	1	8	14	17
Examples of biotechnology	16	34	35	37
Definition of cloning	7	18	18	37
Examples of cloning	41	67	56	77
Definition of GM foods	4	25	20	31
Examples of GM food	2	9	10	17

biotechnology" at all while the other two provided incorrect answers as illustrated below:

> I sort of break it down too, like bio means like humans, bodies and everything, and technology is like the advancement of machines and things to do with that.

Even in years 10 and 12, few students could correctly define biotechnology. Most students did not respond to the question at all. Only one of the six year 10 students interviewed was able to provide a generally accepted definition of biotechnology by stating that "it's the use of like organisms to create something else useful." Three of the six year 12 students interviewed studied biological science. All six of the year 12 students attempted to provide a definition and two were correct. One of the correct responses is presented below.

> Basically to do with research into all applications of technology involving biological things – Whether it be genetic engineering and other things.

On the written survey, about one third of the year 10 students (34%) and year 12 students (36%) provided a correct example of biotechnology. There was no difference between the two groups of year 12 students in respect to the percentage of generally accepted definitions or examples. The most common examples (in decreasing order) across all year groups related to medical uses, environmental uses, agriculture, and GM foods.

Understanding of Cloning

As indicated in Table 1, compared to biotechnology, all year groups were better able to define and provide correct examples of cloning in the survey. The percentage of students able to correctly define or give a correct example of cloning improved from year 8 to 10 to 12 with year 12 biological science students most likely to provide a generally accepted definition (37%) and example (77%). Although about three quarters of the year 8 students who were surveyed (78%) mentioned copying or making a replica of something, only a small proportion stated that cloning involved producing a *genetically* identical copy (7%). Similarly, the year 8 students who were interviewed associated cloning with ‘copying’ or ‘duplicating’ something as the following quote demonstrates:

> It’s making an exact copy of a living or non-living thing.

Year 10 and 12 students were more likely to mention genes in their written responses. These older students were also more likely to use biological terms in their interview responses. In defining cloning, the year 10s who were interviewed used the terms cells (4/6), DNA (1/6) and genes (1/6) as the two quotes below illustrate.

> Like getting the cells and stuff and doubling them and stuff to make it the same.

> It’s copying the DNA to create a like, you know, exact copy of the mother.

Compared to year 8 and 10 students, in both written and oral statements, the year 12s used a broader range of biological terms including cells, genetics, genome, animals, bacteria, genetic engineering, genetic modification and organisms. Five of the six year 12s interviewed were able to correctly define cloning. For example, (cloning is) “just making a copy from the original DNA from the cells, taking them and reproducing.” The most common example of cloning for all year groups was ‘sheep’ or ‘Dolly the sheep.’

Understanding of GM Foods

The percentage of year 8 students able to define GM foods was very low with only 4% (seven students) stating that the DNA was changed. Students were better able to define GM foods in both year 10 (25% correct) and 12 (28% overall correct). Year 12 students studying biological science were most likely to provide a generally accepted definition (31%). The most common correct responses were corn, canola, and soya bean. In the interviews, none of the Year 8s were able to correctly define GM foods although their answers suggested that they believed that GM foods were changed as the following quote suggests.

> It’s sort of like fake ingredients, it’s – Like say if you say it’s pineapple juice and they do it genetically modified, it means it’s not actually pure pineapple juice. It’s sort of copied.

Two of the year 10s who were interviewed were able to provide a generally accepted definition of a GM food but none were able to provide a correct example.

Two of the year 12 students who were interviewed correctly defined GM foods by stating that the DNA was changed as illustrated in the example below.

> Changing the original DNA of fruits and vegetables and that kind of stuff to improve yield, production, colour, taste so they can get more money out of it for less. Ones that use less water and that kind of stuff, so they can spend less money protecting the plant – Like pesticides.

Given the variation in understanding across and within year groups the students who were interviewed were asked where they had learnt about biotechnology. The year 8 students stated that their main sources were TV (4/6) and the news (4/6). The year 10 students who had all studied a 10 weeks genetics topic and studied formal science since year 8, stated that their understanding came from school science (5/6), TV (3/6), news (2/6) and Oprah (1/6). For year 12 students, information came from school science (4/6), TV (4/6), newspapers (4/6) and relatives (2/6). These findings are similar to those of Gunter et al. (1998), who found that the TV news and newspapers followed by school science were primary sources of information about biotechnology by teenagers.

Attitudes Towards Biotechnology Processes

In the attitude section of the survey, students indicated whether or not they found each of 15 statements about a range of biotechnology processes acceptable or not. The statements are listed in Figure 1. The statements relate to biotechnology processes involving the use of micro-organisms, plants, animals or humans. Note that in the actual survey, the statements were not numbered. Nor was the type of organism indicated. The percentage of students in years 8, 10 and 12 who found each statement acceptable is summarised in Figure 2. For all statements except statement

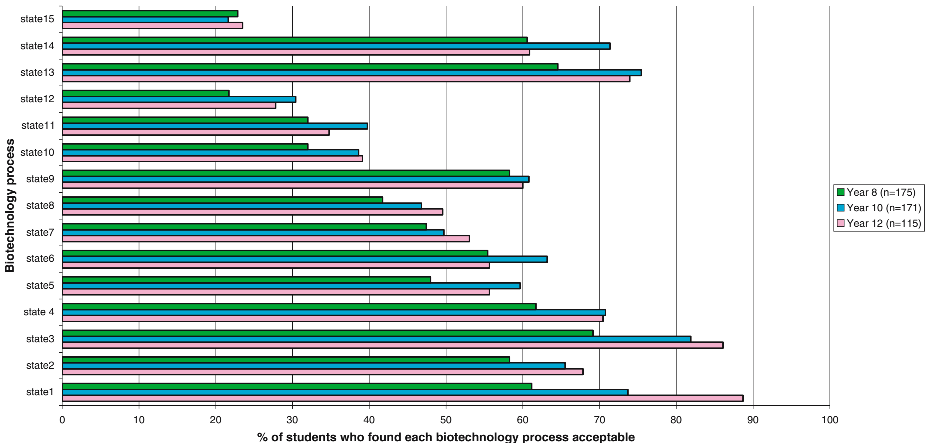

Figure 2 Acceptability of a range of biotechnology processes by students in years 8, 10 and 12

15 where differences are minimal, the year 8 students are less accepting of biotechnology processes than year 10 and 12 students.

For ease of comparison, in Figure 3, average percentages for micro-organisms, plants, animals or humans are presented. Figure 3 indicates, firstly that compared to year 10 and 12 students, year 8 students are less accepting of any biotechnology process regardless of the type of organism involved. Secondly, for all year groups the use of biotechnology processes involving micro-organisms, plants and humans is more acceptable than those processes involving animals. The use of processes involving animals is supported by less than one third of students across all year groups.

The student interview responses indicated that attitudes to cloning and gene technology depend on their context. For example, all of the year 8 and 10 students stated that while cloning of endangered animals was acceptable, human cloning was not. The six year 8 students approved of genetic testing of the foetus for diseases and forensics but were unsure about paternity testing. The six year 10 students also approved of genetic testing for diseases and forensics and 5 of 6 approved of paternity testing. Across all year groups, a greater level of concern was expressed about GM foods. Two of the year 8 students mentioned allergies and poisons as problems associated with GM foods. The year 10 students stated that GM foods could “make people sick,” “cause farmers to lose jobs” and that it was “unnatural.”

The six year 12 students expressed a range of views about biotechnology, cloning, genetic testing and GM foods. Three students thought biotechnology was “good,” one had no view and two were concerned that it was “a dangerous issue” and “could go

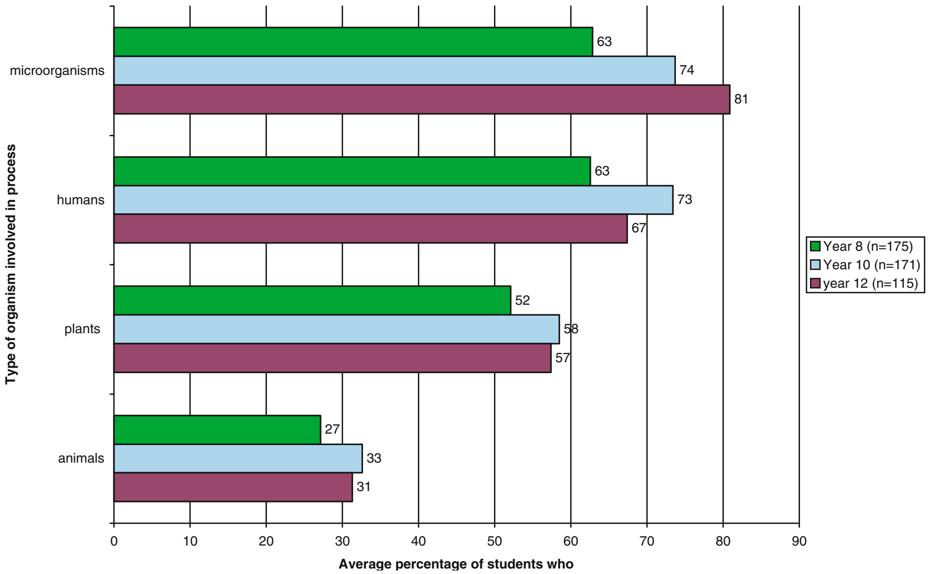

Figure 3 Acceptability of biotechnology processes involving micro-organisms, plants, animals and humans by students in years 8, 10 and 12

too far.” In relation to cloning, students also expressed a range of views. Three agreed with cloning endangered species while three stated no and suggested alternatives.

> No. We’ve already stuffed up all the endangered species so, by doing this we’ll probably stuff up the balance even more, because they’re endangered because of humans.

> There’s other methods, like breeding. We should focus on that rather than just going for the quick fix of cloning other animals. There’s definitely lots of breeding programs.

Another student stated that Dolly had aged prematurely and had a lower resistance to disease.

Three of the students believed that human cloning was wrong as illustrated below:

> I mean, scientifically it’s really interesting. Morally I think it’s quite wrong.

And others urged caution:

> ...but it’s kind of a line where you’re not too sure to cross, like if we get out of control how are we going to stop it and that kind of stuff, and if it falls in the wrong hands then who knows what can happen?

> Cloning as it is, like as a whole, like if you’re doing a human being – cloning the whole human being – is definitely wrong, but I’ve heard cloning just certain bits to eradicate disease and stuff like that – it’s like cloning bits of tissue and stuff like that – I think that’s OK, but there’s got to be a fine line between cloning bits and cloning a whole human being.

Similarly, the interview data showed that the year 12 students’ attitudes to GM foods were variable with three approving and three disapproving. Students recognised benefits related to increased drought resistance and increased food production but also identified potential problems related to reduced genetic variation, GM and non-GM crops interbreeding and allergies.

Conclusion

This research study examined students’ understandings of, and attitudes towards biotechnology processes in years 8, 10 and 12. The results indicate that the ability of students to provide a generally accepted definition and examples of biotechnology, cloning and GM foods was relatively low amongst year 8 students but improved for years 10 and 12 students. This finding is most probably due to a lack of formal instruction about genes, genetics and gene technology. None of the year 8 students who were interviewed mentioned school science as a source of information about biotechnology, while this was the main source of information for older students. The older students were more likely to use scientific language in their responses.

Students in all year groups had a better understanding of cloning than biotechnology and GM foods. This may be due to the extensive media coverage of stem cell cloning. Few students were able to define biotechnology and most students in all year groups, including those who had studied two years of biological science in upper secondary school, were unable to correctly name a GM food. This finding is similar to an earlier study (Dawson & Schibeci, 2003a) where less than 5% of 15–16 year old students could correctly name a GM food. While it seems that studying genetics and biology in high school does enhance students' understanding, a significant proportion of students leave high school knowing very little about biotechnology, cloning and GM foods. These findings are of concern given that changes in Federal government policy are occurring rapidly in relation to biotechnology products and processes. In 2001, legislation was introduced requiring all foods with more than 1% GM products to be labelled. In the past two years, the Federal government agency, the Office of the Gene Technology Regulator has approved the commercial production of six GM crops including Bt cotton and Roundup Ready Canola. However, five of the six Australian States currently have a moratorium on the release of GM crops.

In relation to attitudes, most students in years 8, 10 and 12 approved of the use of gene technology and cloning involving micro-organisms, plants and humans and disapproved of the use of animals. There was variation in approval depending on the context. For example, while most students approved of prenatal genetic testing for genetic diseases and the cloning of endangered species, they disapproved of human cloning and were wary of possible problems with GM foods. Overall, year 10 and 12 students' attitudes were more favourable than those of year 8 students. These findings are consistent with those of Hill, Stanistreet, O'Sullivan, and Boyes (1999) who surveyed 778 UK students aged from 11–18 years. They also found that older students were more likely than younger students to accept the use of genetically engineered animals for medical research. Although the younger students in this study also had a relatively poor understanding of biotechnology processes the authors do not imply a causal relationship. As mentioned in the introduction, there are conflicting findings about whether or not there is a relationship between scientific understanding and attitudes towards biotechnology processes (Chen & Raffan, 1999; Hill et al., 1998).

Despite the increasing importance of these topics in our society, biotechnology is not regularly taught in schools. In a recent Australian study, Steele and Aubusson (2004) interviewed biology teachers about their reasons for not teaching biotechnology despite its inclusion in the State curriculum as an elective and the teachers' sound understanding of the content. They found that while the teachers believed that biotechnology was interesting and important they perceived that parts of the biotechnology topic were too difficult for their students and that they may be disadvantaged in external university entrance examinations. Teachers also felt that that there was insufficient practical work compared to other biology topics.

In a survey of Australian, Japanese and New Zealand teachers, Macer, Asada, Tsuzuki, Akiyama, & Macer (1996) found that while most biology teachers were in favour of teaching about biotechnology issues, 72% believed that they did not have sufficient resources or expertise in the content area. This lack of suitable resources has been addressed in part by the development of *Biotechnology Online* (http://www.biotechnology.gov.au/BiotechnologyOnline), a web site produced by the Curriculum Corporation and funded by Biotechnology Australia, a Commonwealth government organisation which aims to raise public awareness of biotechnology. *Biotechnology Online* offers a wide range of resources including informational text, case studies, experiments, interactive activities, practical work, student worksheets and teacher notes. In New Zealand, a web site designed to assist science and technology teachers in primary and high schools has been developed (http://www.biotechlearn.org.nz). It is hoped that these web sites will encourage teachers to incorporate the topic of biotechnology into the science curriculum.

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