ONLINE ARTICLE

Teaching About Designer Babies & Genetically Modified Foods: Encouraging the Teaching of Biotechnology in Secondary Schools

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It has been over 50 years since Watson and Crick suggested a model for the chemical structure of DNA. In the intervening years, this molecule has been the subject of intense research and experimentation. Today, DNA can be easily manipulated by scientists to alter the genetic make-up of organisms. A newspaper report with the headline, *'Designer' baby gets OK*, appeared in a newspaper in Australia (The *West Australian* newspaper, March 12, 2003, page 3); similar headlines have appeared elsewhere in the world. Headlines like these generate questions such as: What *is* a "designer" baby? How are "designer" babies made? What are the consequences? These are questions that teachers and students need to be able to answer to make informed choices that face them now and in the future.

As educators, we need to ask, *What information do students gain about biotechnology from their compulsory years of science education?* The answer is likely to be "not much" in most cases with some rare exceptions where schools have developed courses to explore the concepts related to genetic manipulation and the associated ethical issues. As science teachers are the key people who will choose to teach or not teach this cutting edge science/technology, it is important to know factors that discourage or encourage them from including biotechnology in the high school science curriculum.

We aimed this study to answer: What are the barriers perceived by teachers to teaching biotechnology? What would encourage teachers to conduct a course in biotechnology with their students? How can teachers' confidence be improved in order to attempt a biotechnology module?

Teacher Knowledge of Biotechnology

As teachers, we have a responsibility to make our students aware of new ideas and information as well as the interpretations and implications of this new knowledge. How well we do this is often dependent on our own knowledge base, attitudes, and beliefs (Gress-Newsome & Lederman, 1999).

Teachers' understanding of biotechnology, as shown from the results of the first part of this survey (Leslie & Schibeci, 2003) varies greatly. The limits of their content knowledge can be broad to include traditional and modern forms of biotechnology or limited to thinking that biotechnology is synonymous with gene technology. Different interpretations of the concept will affect the perception of content and suitability for inclusion into different teachers' science programs. For example, if it is seen as a mostly biological

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content area, physical science teachers may be discouraged from including biotechnology in their teaching program.

It is likely that many Western Australian science teachers would have limited exposure to biotechnology in their formal degree qualifications due to the relatively recent introduction of biotechnology into college and university programs. The average age of science teachers in 2000 was 43 years, with human biology teachers the youngest at 40 years, biology teachers at 42 years, chemistry teachers at 44 years, and physics teachers at 46 years (Science Teachers' Association of Western Australia, 2000). Their content knowledge in biotechnology would therefore be limited as most would have completed their qualifications more than 15 years ago. Our understanding of pedagogical content knowledge (PCK), the skills by which teachers are able to appropriately and effectively facilitate student learning, suggests that it is important to understand what teachers perceive to be the barriers and encouragement to teaching of biotechnology. Accordingly, high school science teachers in Western Australia were surveyed to identify the factors that affect their personal choice of teaching biotechnology in their high school science classes. They were asked to identify barriers to and factors that would encourage them in undertaking a biotechnology course with Year 10 or 11 classes (students aged 15-16 years).

Method

A survey was developed that contained four sections: personal information, understanding of biotechnology, barriers to teaching biotechnology, and factors that would encourage the teaching of biotechnology. Background information on teacher qualifications, years of experience, main teaching area, and professional development in biotechnology were sought. In particular, we were interested to compare data according to teaching area (physical science *vs* biological science) and years of teaching experience. This paper reports the results from the "barriers" and "encouragement" aspects of the survey.

The surveys were sent to the heads of science departments, through the principals, in 33 government (Western Australian Department of Education and Training) senior high schools. The heads of science departments were asked to administer the survey to all of the science teachers in their school. As an incentive to complete and return the surveys, a package of support materials (including a 10-week biotechnology unit program, a set of five practical activities, three activities based on media articles, and a list of relevant Web sites) was offered once the completed surveys were returned. The 33 particular schools were chosen because the science administrators or principals were known to the researchers. Schools were targeted in areas where biotechnology might be important, such as agricultural areas. In addition, schools were targeted because they had a large student population enrolled in the Senior Science course (a science course normally taken by those not interested in university entrance) as it was believed these schools would benefit from the support materials offered. Follow-up phone calls to the known administrators helped improve the return rate of surveys.

About 180 science teachers were targeted in the 33 schools. Completion of the surveys was, however, voluntary and as such 105 were returned (58% response rate). Some returns were late and some lacked important details, so were not included in the data analysis reported here. The sample thus comprised 88 teachers from 19 different schools.

A list of 23 possible barriers (Table 1) and a second list of 23 possible encouragement factors (Table 2) to the teaching of biotechnology were compiled from published research findings, discussions with teachers, and from personal experience. From this list of 23 possible barriers, teachers were asked to indicate which had an impact on their decision to undertake a unit of science in the area of biotechnology by ranking their top five chosen factors. The teachers were asked to do the same type of factor selection and ranking for items on the encouragement list.

Table 1. "Barrier" items presented for teacher selection.

ITEM	BARRIER FACTORS
1.	I have little or no personal knowledge of the content.
2.	There is little or no information available at my school.
3.	I don't know where to find suitable resources.
4.	I have no interest in the area.
5.	My students have shown no interest in the area.
6.	It requires expensive equipment to conduct labs.
7.	It requires too much time to set up activities.
8.	The activities don't work or the results are not clear enough to support the theory.
9.	There are too few activities available.
10.	It requires access to computers.
11.	Computer access in my school is difficult for whole classes.
12.	My students would not be able to cope with the abstract level of the concepts involved.
13.	There is no support from my head of department to try anything like this.
14.	There is no professional development to help me start this unit.
15.	I don't know of anyone else doing this type of unit.
16.	My science program is too crowded to add anything else.
17.	It is difficult to change the established science program at my school.
18.	I am a new graduate and my workload is already huge.
19.	I am near retirement and don't want to try something new.
20.	It will involve a new way of teaching in the classroom, with the use of computers.
21.	It involves too many ethical issues that I don't want to deal with in the class.
22.	Students have opportunity to discuss these matters already in other units.
23.	I would like to but there is no money for professional development.

Results

Of the 88 teachers in the sample, 33 nominated themselves as having a physical science background and 43 a biological science background. The remaining 12 teachers did not classify themselves as having either background. There were 44 teachers with more than 15 years of teaching experience.

Factors Perceived as Barriers to the Teaching of Biotechnology in Year 10 or 11

First, the teachers' responses were analyzed for the group as a whole, then comparisons were made for two major factors: *science disciplinary background* (physical science *vs* biological science teachers) and *length of teaching experience* (less than 15 years *vs* more than 15 years). The first biotechnology degree course in Western Australia was offered at Murdoch University 15 years ago, so this was chosen as the length of teaching experience criterion.

The items were ranked according to percentage selection. The percentages (in parentheses) are the proportion of the sample that chose that item among their five top choices. The number of times an item was selected is indicated in *italics*. Results for the top five ranked items are given in Table 3.

Respondents reported the greatest obstacles to teaching biotechnology topics were their own limited knowledge of content and lack of resources, including information on biotechnology, laboratory materials, and computer access.

The five highest ranked factors for both physical and biological science teachers were the same; however, the ranking differed for the two groups. Not surprisingly, more physical science teachers (48.5%) included lack of content as an obstacle than biological science teachers (34.9%). A lack of content knowledge would clearly be an obstacle for both groups. Additionally, both groups included a lack of resources or knowledge of resources, but further investigation is needed to identify those who have actually searched for information on biotechnology.

Both groups (physical science and biological science) indicated that they perceived computer access as essential or highly desirable for conducting a teaching program in biotechnology. They believed computers would be used to access Web sites for finding and using up-to-date, suitable content information and interactive activities.

Teaching experience is an important variable to investigate as biotechnology is one of the newer degree courses. Teachers with qualifications from more than 15 years ago are unlikely to have studied biotechnology or molecular biology. Even those who did study these areas have dated knowledge as the field is changing so rapidly. More experienced teachers familiar with the science syllabus may have more time to overcome this content knowledge problem by, for example, searching the Internet for information.

Table 2. "Encouragement" items presented for teacher selection.

ITEM	ENCOURAGEMENT FACTORS
1.	a package of materials available for immediate use in the class
2.	simple, concise resources for **me** to learn about biotechnology
3.	local examples that would be of interest to the students
4.	someone I could talk to about the conduct of the program
5.	a chance to try the lab activities with someone who knows what they are doing
6.	a network of people to exchange ideas with
7.	access to tertiary institutions' labs for student activities
8.	a list of useful Web sites for relevant information for me and my students
9.	knowledge of interactive Web sites for problem solving
10.	access to loan equipment for conducting labs
11.	support from colleagues at my school
12.	know what Learning Area outcomes are addressed by the unit
13.	sample assessment items with judging keys available
14.	a range of activities that can be used individually and incorporated into existing units
15.	could talk to someone else who been successful in conducting the unit
16.	access to real life examples of biotechnology
17.	interest shown by students in biotechnology
18.	student involved in treatment using biotechnology
19.	activities that students can do with very little supervision or teacher input
20.	better classroom management skills
21.	more able students
22.	older students
23.	a smaller group of students

Factors Encouraging the Teaching of Biotechnology in Year 10 or 11

Factors which would *encourage* teachers to incorporate biotechnology were also investigated. The items were again ranked according to percentage selection and presented using the same method as the barriers. Results for the top five ranked items are given in Table 4.

All groups, whether based on experience or teaching area, chose the same top 10 items with the first and second ranked items the same. A readily available resource was the factor that would do most to encourage teachers to teach biotechnology. The biological science teachers said that they required local examples (Item 3) above assessment items (Item 13), whereas the physical science teachers ranked assessment items above trying the activities before taking them into the classroom (Item 5). The difference in the fourth ranked item is interesting in that the teachers with less than 15 years experience would like local examples providing relevant materials for students.

Table 3. Ranking **bold**, percentages (in parenthesis), and number of times item was selected of the top five factors chosen *in italics* from the Barriers list (Table 1) by different groups

Item	Factor BARRIERS	Rank overall	Rank Phys	Rank Bio	Rank +15yrs	Rank -15yrs
1.	I have little or no personal knowledge of the content.	**1** (46.6) *41*	**1** (48.5) *16*	**2** (34.9) *15*	**2** (43.2) *19*	**1** (50.0) *22*
2.	There is little or no information available at my school.	**2** (43.2) *38*	**3** (36.4) *12*	**1** (53.5) *23*	**1** (52.3) *23*	**3** (34.1) *15*
3.	I don't know where to find suitable resources.	**3** (39.8) *35*	**2** (45.5) *15*	**3** (34.9) *15*	**3** (40.9) *18*	**2** (38.6) *17*
6.	It requires expensive equipment to conduct labs.	**4** (36.4) *32*	**4** (36.4) *12*	**4** (32.6) *14*	**4** (40.9) *18*	**4** (31.8) *14*
11.	Computer access in my school is difficult for whole classes.	**5** (30.7) *27*	**5** (33.3) *11*	**5** (30.2) *13*	**5** (34.1) *15*	
15.	I don't know of anyone else doing this type of unit.					**5** (29.5) *13*
	N	**88**	**33**	**43**	**44**	**44**

Discussion

The barriers and encouragement factors selected by teachers can be explained in general terms of increasing levels of understanding and teacher confidence in teaching biotechnology. It will determine the selection of instructional strategies for the classroom, the use of appropriate knowledge representations, and the awareness of student misconceptions; all of which are important in promoting scientifically acceptable conceptual development in students. Teacher confidence increases with increasing levels of understanding. This leads to increased diversity in classroom activities (Gabel, 1994) and more open-ended and higher level questioning that encourages students to explore their own ideas (Gess-Newsome & Lederman, 1999).

Other studies have found that the following factors (in addition to a lack of content knowledge) cause teachers to feel uncomfortable about including biotechnology in their science programs: a shortage of funds for equipment, consumables, and time for teacher education (Zeller, 2002). This was supported by our findings: The ranking of barriers (Table 3) Item 6 (*It requires expensive equipment to conduct labs*), Item 14 (*There is no professional development to help me start this unit*), and Item 23 (*I would like to but there is no money for professional development*) were ranked 4th, 6th, and 12th respectively by the whole group.

The highest ranked item to impact the teaching of biotechnology was Item 1 (*I have little or no personal knowledge of content*). Teachers do not appear to have a well-developed idea of the appropriate vocabulary, which may lead to difficulties or limited success in searching for the appropriate resources. This links closely with Item 2 (*There is little or no information in my school*) which ranked overall 2, and Item 3 (*I don't know where to find suitable resources*) which ranked overall 3. These results indicate that having an idea of the types of resources that would be suitable, teachers would need to be able to recognize what is appropriate for their students, taking into account both student ability and interest factors. This is difficult when you don't have the knowledge to know what question to ask or to understand an answer given. Such a package, *Biotechnology Online* (http://www.biotechnologyonline.gov.aul), was widely advertised in schools and has been available for 12 months prior to this investigation. This teaching resource was funded by Biotechnology Australia, an Australian government agency. In addition, the European Initiative in Biotechnology Education (EIBE), National Centre for Biotechnology Education (NCBE) in the UK, and Access Excellence (USA) have produced comprehensive programs covering all the major aspects of biotechnology and are suitable for upper primary and high school students. These teaching resources were developed and have been available online from the mid-to-late 1990s. These packages could be used as a whole unit or parts could be incorporated into existing programs.

The growth of knowledge in the area of biotechnology has outpaced the rate at which an encyclopedia is produced and acquired by schools; therefore the latest hard cover information in school libraries and science faculties can be

Table 4. Ranking **bold**, percentages (in parenthesis) and number of times item was selected of the top five factors chosen *in italics* from the Encouragement list by different groups.

Item	Factor ENCOURAGEMENT	Rank overall	Rank Phys	Rank Bio	Rank +15yrs	Rank -15yrs
1.	a package of materials available for immediate use in the class	**1** (75.0) *66*	**1** (72.7) *24*	**1** (74.4) *32*	**1** (72.7) *32*	**1** (77.3) *34*
2.	simple concise resources for me to learn about biotechnology	**2** (54.5) *48*	**2** (60.6) *20*	**2** (51.2) *22*	**2** (54.5) *24*	**2** (54.5) *24*
3.	Local examples that would be of interest to the students	**4** (33.0) *29*		**3** (39.5) *17*		**4** (36.4) *16*
5.	a chance to try the lab activities with someone who knows what they are doing		**4** (30.3) *10*		**5** (34.1) *15*	
8.	a list of useful Web sites of relevant information for me and my students		**5** (27.3) *9*			**5** (29.5) *13*
13.	sample assessment items with marking rubrics available	**3** (39.8) *35*	**3** (42.4) *14*	**4** (34.9) *15*	**3** (40.9) *18*	**3** (38.6) *17*
14.	a range of activities that can be used individually and incorporated into existing units	**5** (29.5) *26*		**5** (32.6) *14*	**4** (38.6) *17*	
	N	**88**	**33**	**43**	**44**	**44**

five or more years old; several generations in terms of the biotechnological revolution. Textbooks quickly date due to the rapid rate of change in biotechnological knowledge and practices. Access to the Internet is important, but again teachers would need the appropriate vocabulary, access to, and knowledge of how to use computers to search efficiently for suitable resources.

Improvement in both the teachers' personal content knowledge and their PCK would be most important to encourage the teaching of biotechnology. A package of materials would serve both purposes and address encouragement (Table 2) Item 1 (*a package of materials available for immediate use in the class*) and Item 2 (*simple, concise resources for me to learn about biotechnology*). Concise resources would give the background content information for teachers to then find appropriate links to local examples, historical development of the concepts, and other resources. This in turn would improve self-confidence, providing encouragement to try more diverse learning/teaching strategies.

Teachers see an assessment package as important support for teaching biotechnology. It would provide ideas for writing items for specific concepts such as the types of questions that could be used and how to word the question or task to elicit appropriate responses. The quality of the question will influence the quality of the response. Teachers need to develop various ways to access what students know for assessment to be valid and fair (Gabel, 1994). By reflecting on student responses to the assessment tasks, the teacher can recognize common areas of misconception or areas of limited understanding and act to rectify this in the future.

The differences in responses between the biological science and physical science teachers were not substantial. The top five items in both lists were very similar, but in a different order. It could have been a matter of degree of the perceived level of biotechnology knowledge, thus impacting the level of confidence in their ability to teach it effectively to their students.

Physical science teachers ranked (Table 2) Item 5 (*a chance to try the lab activities with someone who knows what they are doing*) and Item 8 (*a list of useful websites for relevant information for me and my students*) at fourth and fifth on their list. Both of these would be very helpful in improving personal content knowledge, whether in an organized group in a lab or individually at their own pace.

There was only one other item added to the top five lists when the information was grouped according to years of experience, and that was Item 14 (*a range of activities that can be used individually and incorporated into existing units*).

This was ranked fourth by teachers with more than 15 years experience. More experienced teachers may be more likely to incorporate activities into existing programs. Their pedagogical content knowledge would allow them to determine the most appropriate place in the established curriculum to substitute or add activities associated with biotechnology. Many of these teachers are more likely to have well established and successful science programs that could cause them to resist large scale changes, but are flexible enough to be able to incorporate new ideas into these existing programs. Incorporating new activities into existing units may be an excellent way in which teachers could introduce biotechnology without having to develop and find time for extra units in an already crowded science program.

There is an ever-increasing number of biotechnology resources available online every year. Teachers are becoming aware of the "cutting edge science" nature of biotechnology, through newspaper articles and television programs, in that it is controversial, practical, and relevant and engaging for students. As many of the biotechnology processes are based in understanding the chemistry of DNA and enzymes, physical science teachers could find this an engaging and novel way of addressing these concepts in cross-curricular science programs.

There are opportunities to integrate biotechnology concepts across the science curriculum. It is an excellent platform for developing students' skills of investigation as well as promoting their scientific and technological literacy, leading toward a sound basis for scientific and technological citizenship.

It is very important to target teacher professional development where it will have the greatest effect, especially when resources are limited. In recognizing the main barriers and factors offering encouragement to introduce biotechnology into the science curriculum in high schools in Western Australia, we can address specific areas of need as identified by the people who are the instigators of change: the teachers.

The work that is being done through the *Farm to Plate Project* at Murdoch University addressed the issues of barriers and encouragement through the development and production of resource materials and the presentation of teacher professional development. When teachers attend the biotechnology professional development courses, they are provided with locally produced resource materials, a sample science program unit, an annotated list of Web sites appropriate for high school students, and practical activities and student activities based on newspaper articles. They carry out some of the sample laboratory experiments to get an understanding of the process, likely problems, and results. They were also given a guided tour of the Australia-produced *Biotechnology Online* education Web site and allowed time to explore other sites from the list given. The only item ranked in the top five encouragement factors not addressed in the teacher professional development is that of assessment. Workshops are planned for the near future to assist teachers in constructing assessment items that allow students to demonstrate their knowledge at a range of different conceptual levels, across different aspects of biotechnology, and in line with local educational standards. As a result, biotechnology has become an established part of the science programs of three different schools where it was not present before.

The differences between the groups were not great, leading to the conclusion that the barriers and encouragements are professional concerns for all science teachers and not problems of individual groups of science teachers. Materials produced and used in teacher professional development would need to address these concerns from the perspectives of different groups of science teachers to encourage their engagement and teaching of biotechnology in their specific areas of expertise.

This study had a self-selected population from among the group of schools we decided to specifically target. It would appear that our numbers may be skewed in that the teachers who did not return the survey were probably not interested in teaching biotechnology, even with the promise of teaching resources on return of the survey. On subsequent inquiry to some schools with low returns, it was noted that it was mainly the physical science teachers who did not complete the survey because they did not think biotechnology was part of their teaching area. One returned form from a physical science teacher did not have any of the encouragement factors checked; does that mean biotechnology would not be a part the science program in that person's classes at all? On another returned form, the Barrier Factors included: "None of these would affect my decision. I would undertake a unit of science in the area of biotechnology." Despite all the barriers, there are still teachers who are willing to try new things.

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