Students' And Teachers' Perspectives On Biotechnology Education: A Review On Publications In Selected Journals

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Abstract: Modern biotechnology has brought a lot of changes in science and technology. As a scientific discipline, modern biotechnology goes hand in hand with cultural, social, and public policy controversies, the development of theories and techniques enables scientists to alter the genetic code of all living organisms practically. Science education is to enhance the scientific and technological literacy in each and every child. Young people need to be informed, not only about the practical applications of biotechnology, but also of the need to appreciate the social and ethical implications so that they can make wise personal choices and contribute to public debate in the future. The present study intends to explore the trend of research conducted on students and the in- service and pre-service teachers. Besides that, the findings of the research will also be discussed in-depth. The articles were analyzed by publication year, journal, and research topic categories. Results for the most and least published research topics can indicate the overall patterns and research trends in this field. The discussion carried out focused on the related articles published in a few journals from the year 2000 until 2012. Some recommendations were also discussed. [Rashidah BG, Norlidah A, Mohammad A. **Students' And Teachers' Perspectives On Biotechnology Education: A Review On Publications In Selected Journals.** *Life Sci J* 2013;10(1):1210-1221] (ISSN:1097-8135). http://www.lifesciencesite.com. 186

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1. Introduction

Modern biotechnology has brought a lot of changes to science and humankind. As a scientific discipline, modern biotechnology goes hand in hand with cultural, social, and public policy controversies; the development of theories and techniques enables scientists to alter the genetic code of all living organisms practically. Biotechnological applications of all kinds are in the making and already evident in a growing range of genetically modified foods in supermarkets (Klop, Severiens, Knipples, Van Mil, & Ten Dam, 2010). Besides that, biotechnology was the impetus in the rapid development in biomedical (Dawson & Cowan, 2003), agricultural and industrial breakthroughs. Despite its potential, however, biotechnology continuously challenges the public by raising many controversial issues (Hanegan & Bigler, 2009).

An important outcome of science education is to enhance the scientific and technological literacy in every child; this has been universally welcomed as a desirable goal for education (Hodson, 2003). A high level of scientific literacy can help young people to question the claims of the scientific community and enable them to use their understanding of science to make well-informed ethical decisions. Young people need to be informed, not only about the practical applications of biotechnology, but they also need to appreciate the social and ethical implications so that they can make wise personal choices and contribute to future public debate (Dawson & Schibeci, 2003). Science education researchers and practitioners endeavour to promote scientific literacy based on the premise that the ability to make informed decisions about socio-scientific issues is essential for an active and balanced citizenship (Bryce & Gray, 2004; Fonseca, Costa, Lencastre, & Tavares, 2012).

Given the importance of biotechnology, some of the related topics have been incorporated in school science curricula in a few countries (Hanegan & Bigler, 2009; Kwon & Chang, 2009; Steele & Aubusson, 2004). Despite all efforts to incorporate biotechnology into the school curriculum, some related issues have emerged. Studies conducted in countries such as South Korea, Portugal, Scotland, Spain and New Zealand, have shown that the teachers tend to avoid teaching biotechnology-related topics. They reason that they had inadequate academic training, insufficient resources for experimental activities, time constraints and lack of funding (Bryce & Gray, 2004; Hanegan & Bigler, 2009; Kwon & Chang, 2009; Steele & Aubusson, 2004).

In this context, the present study intends to explore the trend of research conducted on students, in- service and pre-service teachers. Besides that, the findings of the research will also be discussed in-depth. The articles on biotechnology were analyzed by publication year, journal title, and research topic categories. Results for the most and least published

research topics can indicate the overall patterns and research trends in this field. The discussion carried out will be focused on the related articles published in a few journals from 2000 until 2012.

In addition, looking at the trend of current research studies can help researchers get some ideas of the kind of research that has been carried out and the new areas that need to be focused in this field. Besides that, the appropriate agencies and policy makers in related fields can use the findings from this article to guide them in their future research.

Therefore, this article will try to find the answers and get some insightful view of the biotechnology education carried out in some countries. The research questions addressed by this study are:

1. What were the trends of research on students with reference to biotechnology education?
2. What were the trends of research on teachers with reference to biotechnology education?
3. What were the research findings on students with reference to biotechnology education?
4. What were the research findings on teachers with reference to biotechnology education?

2. Methodology

The main focus of this study is to gather some information over the trend of research carried out and published in journals regarding Biotechnology Education. This was done by using the Education Journals@ProQuest database as a source to gather the number of articles which have been published in journals related to the field of science, biology, technology, teaching and innovation. The publication years for each article were only limited from 2000 until 2012. This is to ensure that the research conducted in these years will discuss the latest findings as we know that biotechnology is a field still undergoing rapid changes. New findings and innovations are discovered and added to the knowledge base and changes are still taking place.

Using the search terms 'biotechnology', `education',`teacher' and 'school'; and narrowing down to only the articles published between 2000 - 2012, it was found that there were 19 articles related to these studies.The articles were categorised according to their field of research. Mainly there were two categories seen; concentrating on students, preservice and in-service teachers.Then, the articles were further analysed by going through the abstract and the whole research paper. Related to the two categories mentioned above; the findings and the suggestions highlighted by the researchers were analysed.

3. Results

3.1 Trends of research on students with reference to biotechnology education

From the journals searched through the Education Journals@ProQuest database, there were eight main journals in which articles on biotechnology education have been published. As shown in Table 1, out of the nineteen articles reviewed, the highest number of eleven articles (58.0%) were published in the International Journal of Science Education, followed by three (16.0%) in the Journal of Biology Education. The other journals were less popular and the percentage of articles published were only 5.2%. This may be because the area of biotechnology teaching is mainly from these two major subjects. Therefore, it can be seen that the biotechnology in education field is generally infused into the subject of science and biology although in some countries this topic stands on its own as a subject known as biotechnology.

Table 1. The distribution and percentage of research articles from 2000 - 2012

No.	Journals	Fre-quency	Percen-tage(%)
1	International Journal of Science Education	11	58.0
2	Journal of Biology Education	3	16.0
3	Italian Journal of Food Science	1	5.2
4	Teaching and Teacher Education	1	5.2
5	Journal of Technology Studies	1	5.2
6	International Journal of Environmental and Science Education	1	5.2
7	Research in Science & Technological Education	1	5.2
	Total	19	100

From Figure 1, the highest number of research done was in the students' attitude. There were three articles was on attitude solely and another three were a mixture of attitude and another category of interest; that was values,understanding and one particular article was basically on an instrument developed to measure students' attitude. Beside that, two articles were on students' perception respectively and their debating ability on biotechnology topic. The other area of interest was students' understanding, ethical and knowledge, and reasoning and argumentation.

Table 2: Student: The research title, authors and year published in the main journals

No.	Journals	Article Title	Focus	Authors (Year)
1	Interna-tional Journal of Science Educa-tion	A study of pupils' conceptions and reasoning in connection with 'microbes', as a contribution to research in biotechnology education.	Con-cept and reaso-ning	Simonneaux (2000)
2	Journal of Biology Educa-tion	Analysis of classroom debating strategies in the field of biotechnology.	Debate Strategies	Simonneaux (2002)
3	Journal of Biology Educa-tion	Western Australian high school students' attitudes towards biotechnology processes.	Atti- tude	Dawson & Schibeci (2003a)
4	Interna-tional Journal of Science Educa-tion	Western Australian school students' understanding of biotechno-logy.	Under-standing	Dawson & Schibeci (2003b)
5	Re-search in Science & Techno-logical Educa-tion	The effect of biotechno-logy education on Australian high school students' understan-dings and attitudes about biotechno-logy processes.	Under-standing and attitude	Dawson & Soames (2006)
6	International Journal of Science Education	An explora-tion of attitudes towards modern biotechno-logy: A study among Dutch secondary school students.	Attitude	Klop & Severiens (2007)
7	International Journal of Science Education	Matching society values: Students' views of biotechno-logy.	Values and attitude	Saez, Niño, & Carretero (2008)
8	International Journal of Science Education	High-school students' informal reasoning and argumenta-tion about biotechno-logy: An indicator of scientific literacy?	Reasoning and argumentation	Dawson & Venville (2009)
9	International Journal of Science Educa-tion	Effects of a science education module on attitudes towards modern biotechno-logy of secondary school students.	Attitude	Klop, Severiens, Knipples, Van Mil, & Ten Dam (2010)
10	Interna-tional Journal of Science Educa-tion	High school students debate the use of embryonic stem cells: The influence of context on decision-making	Debate and decision making	Molinatti, Girault, & Hammond (2010)
11	Italian Journal of Food Science	Risk perception about GMOS and food choices among adolescents attending secondary schools: A Tuscan case.	Perception	Bonaccorsi, Levi, Bassetti, Sabatini, Comodo, & Lorini. (2010)
12	International Journal of Science Educa-tion	Is judgement of biotechnological ethical aspects related to high school students' knowledge.	Ethics and knowledge	Črne-Hladnik, Hladnik, Javornik, Kosmelj, & Peklaj (2011)
13	International Journal of Science Educa-tion	Development and validation of the GMOAS, an instrument measuring secondary school students' attitudes towards genetically modified organisms	Mea-sure atti-tude	Herodo-tou, Kyza, Nico-laidou, Hadji-chambis, Kafouris,, & Terzian (2011)
14	Journal of Biology Educa-tion	Multidi-men-sional analysis of high-school students' Perceptions about biotechno-logy.	Per-ception	Fonseca, Costa, Lencastre, & Tavares (2011)

Table 3. Teachers: The research title, authors and year published in the main journals

No.	Journals	Article Title	Focus	Authors (Year)
1	International Journal of Science Education	Tough acts to follow: The challenges to science teachers presented by biotechnolo-gical progress	Thinking	Bryce & Gray (2004)
2	International Journal of Science Education	Slovakian **students'** knowledge of and attitudes towards biotechnology	Attitude, Know-ledge	Prokop, Les-kova, Kubiat-ko & Diran (2007)
3	Journal of Technolo-gy Studies	Technology teachers' belief about biotechnology and its instruction in South Korea	Belief	Kwon & Chang (2009)
4	International Journal of Environ-mental & Science Education	American elementary education pre-service teachers' attitudes towards biotechnology processes.	Attitude	Chabalengula, Mumba & Chitiyo (2011)
5	Teaching and Teacher Education	Disclosing biology teachers' beliefs about biotechnology and biotechnology education	Belief	Fon-seca, Costa, Lencas-tre, Tava-res (2012)

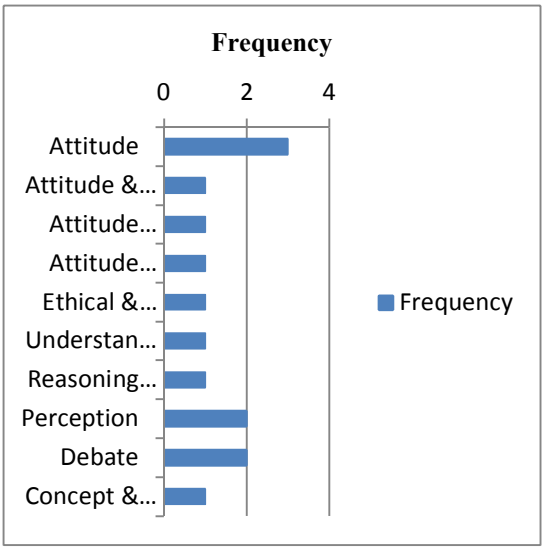

Figure 1: Frequency count on the research areas on students related to biotechnology education out of 20 selected journals

Further analysis was conducted to learn what were the research titles, author and the year of publication of the journal articles. From Table 2 and Figure 1, it was found that there is a change in the trend of research carried out throughout the years. Simonneaux (2000) conducted research focused on the concept and reasoning ability of the students regarding microbes in general and bacteria and virus specifically. This is seen as important because it will be the foundation for better student understanding about microbes as gene vectors. The same author in 2002 analysed the classroom debating strategy of students. He had presented a method for analysing the didactic strategies to develop students' argumentation skills in biotechnology. To become a scientifically literate citizen, the student must be guided to have the strategy of debating and knows about the pros and cons of the matter being argued.

Out of 19 journal articles, 14 were on students mainly in secondary and high school, and the rest were articles on pre-service and in-service teachers as shown in Table 2 and Table 3.

Dawson and Schibeci (2003a) conducted a study on students' attitude and understanding. It is quite clear that understanding is a crucial element that must be tackled so that students can use their knowledge about biotechnology and then build an appropriate attitude. Therefore, from 2003 until 2010, a vast number of studies were done on the student attitudes; either in secondary or high school. It can be seen that some of the researchers even tried to find the relationship between the attitudes of a student with other factors, such as knowledge and values. Knowing the importance of measuring attitude with a standardized instrument, especially about the genetically modified organisms; Herodotou et al. (2011) developed the tool and reported that Cypriot secondary school students had rather non-supportive attitudes towards GMO cultivation and use.

Not only that, some researchers had also explored students' ability to reason and argue when engaged in discussion or debate. Fonseca, Costa, Lencastre, and Tavares (2011) had conducted a multidimensional analysis of high-school students' perception about biotechnology. They evaluated education and gender effects on knowledge, attitudes, interest and importance given to biotechnology by the students. It was noticed that the focus of the reserach conducted still linger around the same themes.

Out of all the research articles analysed, it can be concluded that most of the research discussed the same areas of interest. None of the research papers tried to explore the students' cognitive levels, their metacognitive skills and how they think about the issues and ways to solve problems.

Besides that, it can be noticed that a gap exists that can be bridged. In accordance to the findings, it is also noticed that the research were mainly from the western part of the world. None of the articles on students were published which originated from the Asia region generally and the Asia Pacific region specifically. What is going on in these countries in relation to biotechnology education in the schools were not being thrust out and shared by the rest of the world. It will be valuable if the approach and the currriculum aspects can be explored and discussed further.

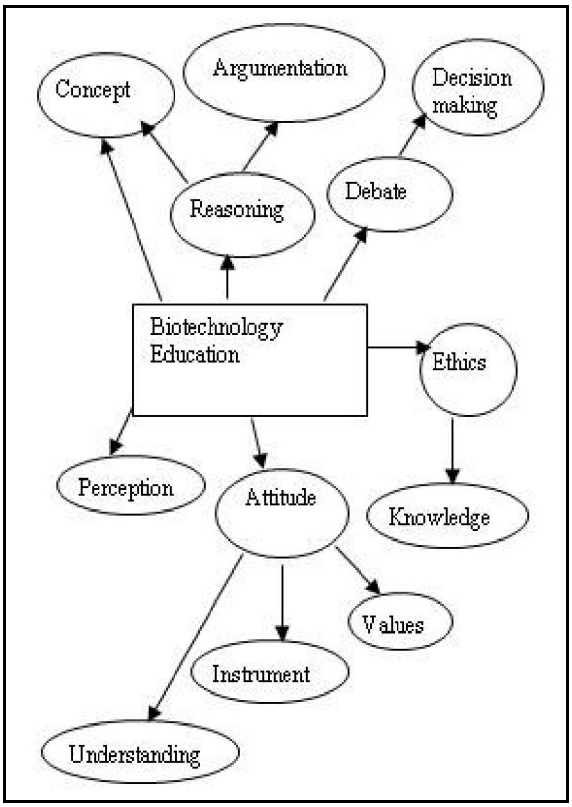

Figure 2. Concept map of research focus of students in biotechnology education.

3.2 Trend of research on teachers with reference to biotechnology education

From the research articles gathered, only five articles published in the selected journals focused on teachers, as shown in Table 3. Two out of the five articles were about the teachers' beliefs on biotechnology or biotechnology education. One discussed the attitude of the pre-service teachers, the others were about the thinking of the in-service teacher and one was on the attitude and knowledge of pre-service teachers.

Bryce and Grace (2004) conducted a study focused on the thinking of biology science teachers who attempted to implement the first year of the New Scottish Advanced Higher Biology course and the challenges they faced associated with biotechnology controversies. Kwon and Chang (2009) studied the technology teachers in South Korea on their belief about biotechnology and its instruction. The same trend was noticed when Fonseca et al. (2012) did research on the same aspect but it was on the biology teachers in biotechnology and biotechnology education recently. It can be deduced that biotechnology education involves teachers in different fields. Some countries leave it in the hands of science teachers, whereas others leave it to the biology teachers and some leave it to the technology teachers. So far, no findings on agricultural teachers from other countries involved in biotechnology teaching have been reported in the journals selected for this article.

From Figure 2 and Table 3, it is clearly seen that the most research conducted from the reviews was on teachers' belief which has two articles and the other articles was on teachers' thinking, attitude and also knowledge.

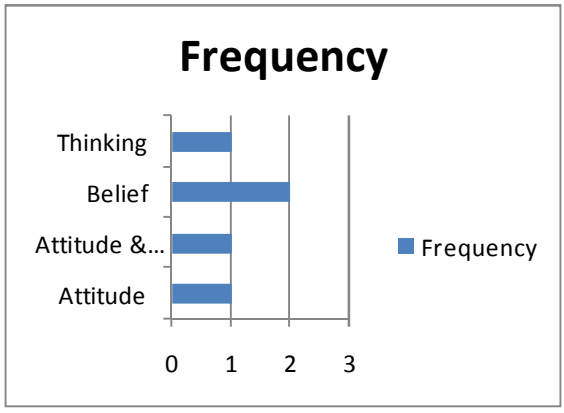

Figure 3: Frequency count on research areas on teachers related to biotechnology education

As attitude was the main focus in students research reported in the articles reviewed; it is observed that there is one article by Chabalengula et al. (2011) which was also interested to know about pre-service teachers' attitudes towards biotechnology processes. As seen in the research relating to students, not much attention has been given to teachers; either the in-service or the pre-service. A lot of opportunity remains to be researched and explored further in this area. New researchers should try to look into the other areas still unexplored. Perhaps, by looking at another angle, we will be able to see a bigger scope and solve another puzzle.

3.3 Research findings on students with reference to biotechnology education

The findings from the selected articles will be discussed under seven major categories. There are basically attitude, perception, understanding, reasoning, debate, ethics, and values.

3.3.1 Attitude

Six research articles in this study related to attitudes of the students from secondary and high school as shown in Table 4.

In the research on Western Australian high school students' attitude, Dawson and Schibeci (2003a) found that the students held a wide range of beliefs about what constitutes acceptable use of biotechnology. Six percent of the students did not agree with the use of any living organisms in biotechnology and some 14% of them approved all the stated uses of biotechnology, with a wide spread of students having mixed reaction in between. Beside that, the students' acceptance of the use of organisms in biotechnology decreased; 90% of students approve the use of microorganisms, 71 – 82% approve the use of plants, 42 – 45% of students approve the use of human and 34 – 40% of students approve of using animals in biotechnology. In this research the author suggested that the biotechnology processes and associated issues should be included in the science curriculum.

Studies by Klop and Severiens (2007) found four different group of students based on their attitude towards biotechnology. The four groups are labelled as "confident supporter" (22%), "not sure" (42%), "concerned sceptic" (18%), and "not for me" (17%). While Dawson and Soames (2006) found that the students felt that usefulness was one of the values considered best when supporting biotechnology applications, precautionary measures must be taken to guarantee reduction of risks to health and environment.

Dawson and Soames (2006) mentioned that after completing a biotechnology course, students' understanding increased but their attitudes remained constant with the exception of their views on human uses of gene technology. While Klop et al. (2010) discovered that the students exposed to science modules on cancer and modern biotechnology showed that the science module had a significant effect on attitudes, although predominantly towards a more supportive and not towards a more critical stance. Therefore, offering science modules of this kind can indeed encourage students to become more aware of modern biotechnology, although promoting a more critical attitude towards modern biotechnology should receive more attention.

Looking at the trend of research conducted by other researchers, Herodotou et al. (2011) developed a 16-item, five-point Likert-type instrument, GMOAS, which showed satisfactory internal consistency and discriminant validity. When the instrument was used to analyse data from Cyprus, results revealed that Cypriot secondary school students have rather non-supportive attitudes towards GMO cultivation and use. Male students were less negative in using GMOs for health and environmental purposes than female students. Surprisingly, female students were found to be more interested in learning about GMOs. From the six research studies discussed, we concluded that the attitudes of the students are varied and do not show a similar trend. The underlying factors that probably have an influence in the attitude of the students need to be known.

Table 4: Related articles on students attitudes towards biotechnology education

No.	Article Title	Authors (Year)	Research Objectives
1	Western Australian high school students' attitudes towards biotechnology processes.	Dawson & Schibeci (2003a)	To explore attitudes held by 15 – 16- year-old students (Year 11) about biotechno-logy processes
2	An exploration of attitudes towards modern biotechnology: A study among Dutch secondary school students.	Klop & Severiens (2007)	To explore decision-making and critical attitudes in secondary school students (16 years old).
3	Matching society values: Students' views of biotechnology.	Saez, Nino & Carretero (2008)	i.Exploring the different cultural contexts in which biotechno-logy teaching and learning is embedded. ii. Students' attitudes and values.
4	Effects of a science education module on attitudes towards modern biotechnology of secondary school students.	Klop, Severiens, Knipples, Van Mil & Ten Dam	To evaluate the impact of a four-lesson science module on the attitudes of secondary school students.
5	The development and validation of the GMOAS, an instrument measuring secondary school students' attitudes towards genetically modified organisms	Hero-dotou, Kyza, Nicolai-dou, Hadjichambis, Kafouris & Terzian (2010)	To present the delopment and validation of the genetically modified organisms attitude scale (GMOAS),an instrument measuring secondary school students'attitude towards GMOs.
6	The effect of biotechnology education on Australian high school students' understandings and attitudes about biotechnology processes	Dawson & Soames (2006)	To determine the effect of biotechno-logy education on Year 10 (15 years old) adolescents' understanding and attitudes about processes associated with biotechno-logy.

3.3.2 Perception

There are two articles on perception; one each on secondary school and high school students as shown in Table 5.

The research related to perception can be considered as a new trend in biotechnology research because it was published in 2010 and 2011. Bonaccorsi et al. (2010) in their study investigated the students' risk perception of biotechnology and GMOs and found that students knowledge seemed rather confused. To rectify these issues, education training needs to train teachers on the pedagogical aspect on how to teach biotechnology. Not only that, schools were suggested to serve as a channel through which physicians and other professionals in biotechnology can convey beneficial information to students.

Table 5: Related articles on students perceptions towards biotechnology education

No.	Article Title	Authors (Year)	Research Objectives
1	Risk perception about GMOS and food choices among adolescents attending secondary schools: A Tuscan case.	Bonaccorsi, Levi, Bassetti, Sabatini, Comodo, & Lorini. (2010)	To investigate students (17-18 years old) risk perception of biotechnologies, in general and GMOs, in particular.
2	Multidimensional analysis of high-school students' perceptions about biotechnology	Fonseca, Costa, Lencastre & Tavares (2011)	Evaluates education and gender effects on knowledge, attitudes, interest, and importance given to biotechnology.

The second research by Fonseca, Costa, Lencastre, and Tavares (2011) was a multidisciplinary analysis of students from science and non-science courses. Students particularly those from non-science courses, revealed knowledge and interest limitations, but they still acknowledged the importance of biotechnology. Most students demonstrated positive attitudes towards different applications, except when animal manipulation was involved. Positive correlations seen between knowledge, attitudes, interest and importance attributed to biotechnology were identified.

3.3.3 Understanding

Two related articles on understanding were found and both the research were performed on students in Australia. Table 6 shows the detailes of the research caried out.

While Dawson and Schibeci (2003b) who studied 1116 Year 10 Western Australian students showed that one third of students (33.5%, 374) were unable to give an example of biotechnology; some 23.3% (250) students were unable to give an example of genetic engineering. About 19% (204) students were unable to give an example of cloning. As a whole, one third of the survey result indicated students had little or no undertanding of biotechnology. Many students over-estimated the use of biotechnology in society by confusing current uses with possible future applications.

In 2006, Dawson and Soames (2006b) conducted research on the effect biotechnology education had on high school students. After completing a biotechnology course, students' understanding was increased but their attitudes remained constant with the exception of their views about human uses of gene technology. These two articles showed that the level of understanding between this two sample were considered low. More research must be done with the intention to boost up students' level of understanding.

Table 6: Related articles on students understanding towards biotechnology education

No.	Article Title	Authors	Research Objectives
1	Western Australian school students' understanding of biotechnology.	Dawson & Schibeci (2003b)	To assess whether students were able to make an informed contribution to public debate about issues such as cloning of human cells to produce a new individual, or the cultivation of genetically modified crops. To determine their understanding towards biotechnology issues above.
2	The effect of biotechnology education on Australian high school students' understandings and attitudes about biotechnology processes.	Dawson & Soames (2006)	To determine the effect of biotechnology education on Year 10 (15 years old) adolescents' understanding and attitudes about processes associated with biotechnology

3.3.4 Reasoning

There are two articles related to this category as shown in Table 7.

In the study carried out by Simonneaux (2000), the findings showed that students were vague about the exact nature of 'microbes'. Bacteria was often seen solely as decomposing agents, while viruses and bacteria were only more or less seen as involved in pathological conditions. Beside that, only some of them knew about how bacteria was used in industry. Some students simply could not conceive how 'microbes', which were necessarily harmful, could possibly be used to manufacture food.

It was suggested that the teaching of biotechnology should start with historical facts and some input on prokaryote biology; students should be encouraged to understand how 'microbes' can be involved both in pathological conditions and in industrial uses, including genetic manipulation.

A related study by Dawson and Venville (2009) showed that the students mostly used no data or only simple data to justify their claims during their argumentation. Students of all year groups used intuitive and emotive informal resoning more frequently than rational.

Table 7: Related articles on students reasoning ability towards biotechnology education

No.	Article Title	Authors (Year)	Research Objectives
1	A study of pupils' conceptions and reasoning in connection with 'microbes', as a contribution to research in biotechnology education.	Simonneaux (2000)	To identify the difficulties encountered by students as they attempt to comprehend current and future biotechno-logy.
2	High-school students' informal reasoning and argumentation about biotechnology: An indicator of scientific literacy?	Dawson & Venville (2009)	To explore Australian high-school students' argumenta-tion and informal reasoning about biotechno-logy.

Rational informal reasoning was associated with more sophisticated arguments. Arguments were not consistent with the goal of scientific literacy of the curriculum that underpins the education of these students. The approach of using both levels of argumentation and patterns of informal reasoning to analyse each statement made by students enabled greater insight into the data and introduces a new and unique method that can be used by other researchers.

3.3.5 Debating

There are two research articles on student reasoning as shown in Table 8.

Simonneaux (2002) showed that reverse shown by some of the students in the debate. Teachers also found it difficult to remain neutral when leading a debate. It was suggested that the didactic strategy involving class discussions, whether through role play or debate, would seem to be a useful way of helping students to develop their arguments. Teachers were encouraged to adapt activities to their students' ability.

Reference to Molinatti, Girault, and Hammond (2010) in the findings showed that analysis of the students' arguments and decision-making revealed that contextualization introduced dynamism in the students' exchanges. The students paid more attention to their peers' arguments and were more motivated to argue their own opinion. However, this type of contextualization may contribute to reinforcing ideology in scientific progress.

Table 8: Related articles on student reasoning ability towards biotechnology education

No.	Article Title	Authors (Year)	Research Objectives
1	Analysis of classroom debating strategies in the field of biotechnology	Simonneaux (2002)	Presents a method for analysing the didactic strategies put forward to develop students' argumenta-tion skills in biotechno-logy.
2	High school students debate the use of embryonic stem cells: The influence of context on decision-making	Molinatti, Girault, & Hammond (2010)	To analyze decision-making and argumenta-tion by high school students in a debate situation on socioscien-tific issues, the use of emryonic stem cells in research and therapy. Influence on the debates of two different contexts was tested.

3.3.6 Ethics

There is one research article related to students'ethics as shown in Table 9.

Table 9: Related articles on students ethics towards biotechnology education

No..	Article Title	Authors (Year)	Research Objectives
1	Is judgement of biotechnological ethical aspects related to high school students' knowledge	Ćrne-Hladnik, Hladnik, Javornik, Kosmelj, & Peklaj (2011)	To explore relationship among students' pre-knowledge of molecular and human genetics,and their attitudes to four specific biotechno-logical applications.

Molinatti et al. (2010) found clear gender differences regarding the relationship between students' pre-knowledge of genetics and their attitudes to biotechnological applications. Females with a better genetics background expressed a higher risk perception in the case of GM salmon. Males emphasised the risk associated with the use of germ line GT. With all four biotechnological applications, patterns of both rationalistic – deontological and teleogical – and intuitive moral reasoning were identified. Students with poorer genetics pre-knowledge applied an intuitive pattern of moral reasoning more frequently than their peers with better pre-knowledge.

A pattern of emotive reasoning was detected only in the case of GM salmon. A relatively low quality of students' moral reasoning, as demonstrated by their brief and small number of supporting justifications (explanation), showed there was a strong need for practising skills of argumentation about socio-scientific issues in Slovenian high schools on a much larger scale.

Some suggestions thrown by the researcher was that biology teachers must be equipped well enough to teach these controversial topics, so that they would undoubtedly feel more confident to discuss various moral issues. Cooperation was suggested between biology teachers and social science subject teachers, such as sociology, psychology and philosophy.

3.3.7 Values

There is one research article related to students' values as shown in Table 10.

Table 10: Related articles on students values towards biotechnology education

No.	Article Title	Authors	Research Objectives
1	Matching society values: Students' views of biotechnology	Saez, Nino & Carretero (2008)	i.Exploring the different cultural contexts in which biotechnology teaching and learning is embedded. ii.Attitudes and values of students.

This study used a case study approach involving 770 students in the health science or technology fields from 13 secondary schools.The findings showed that ethical and moral issues played a significant role in shaping attitudes towards applications of modern biotechnology among young people. Four main values were identified from this research, namely: principles of the natural, principle of the welfare, principle of the technological solution attitude and lastly principle of the individual decisions. All the main values are important to cultivate a good set of values that the student will have and use as an informed and scientifically literate citizen later on.

3.4 Research findings on teachers with reference to biotechnology education

The findings from the selected articles will be discussed based on three major categories of attitude, belief and thinking.

3.4.1 Attitude

There are two research article related to teachers'attitude as shown in Table 11.

Although Chabalengula, Mumba, and Chitiyo (2011) focused on elementary pre-service, it was considered a valuable information for the other teachers as well. The elementary education pre-service teachers from both the introductory Science methods and the Advance Science methods course generally held a wide range of attitudes towards biotechnology education.

Table 11: Related articles on teachers attitude towards biotechnology education

No.	Article Title	Authors	Research Objectives
1	American elementary education pre-service teachers' attitudes towards biotechnology processes	Chabalengula, Mumba & Chitiyo (2011)	To examine elementary education pre-service teachers' attitudes towards biotechno-logy processes.
2	Slovakian students' knowledge of and attitudes towards biotechno-logy	Prokop, Leskova, Kubiatko & Diran (2007)	To examine preservice teachers' knowledge of and attitudes towards biotechnology courses.

The majority of pre-service teachers approved the genetic modification of microorganism and plants, but disapproved the processes that involved the insertion or removal of genes in human and animals. Some suggestions made by the researcher were that university teachers were charged with developing science education curriculum materials that would enable pre-service teachers to acquire relevant and current information about what biotechnology contributed to our personal and societal lives as well as its shortfalls. It was also hoped that they would have a better understanding of ethical, social and cultural issues related to biotechnology.

Prokop et al. (2012), whose research was on pre -service teachers, showed that the students had a poor knowledge of what biotechnology processes mean. Females students show less positive attitudes toward biotechnology regardless of their knowledge about genetic engineering. The most negative attitudes were found in items related to control of genetic engineering. On top of that, about one-half of the students thought that genetic modification was painful for animals and other 41% thought that consumption of GM foods could destroy human genes.

3.4.2 Thinking

Only one study from the research articles related to teachers' thinking as shown in Table 11.

Table 11: Related articles on teachers' thinking towards biotechnology education

No.	Article Title	Authors	Research Objectives
1	Tough acts to follow: The challenges to science teachers presented by biotechnological progress	Bryce & Gray (2004)	Focused upon the thinking of biology teachers as they attempted to implement the first year of the new Scottish Advanced Higher Biology course and to face the challenges associated with these controversies.

In this research, although teachers were found to be fairly positively disposed to handling discussion of such contenious matters, they were none too clear as to its precise merits and functions. Many teachers were lacking in confidence while handling discussion. It was suggested that this emerging problem needs to be tackled by way of professional development for science teachers who are now engaged in dimensions new to science teaching. A developed pedagogy is required and teachers must have the confidence and it should increase accordingly.

3.4.3 Belief

There are two research articles related to teachers' belief as shown in Table 12.

Table 12: Related articles on teachers belief towards biotechnology education

No.	Article Title	Authors	Research Objectives
1	Disclosing biology teachers' belief about biotechnology and biotechnology	Fonseca, Costa, Lencastre & Tavares (2012)	To under-stand the extent to which teachers's engagement in biotech-nology teaching is influenced by their beliefs and /or by extrinsic con-straints, such as practical limitations; To evaluate biology teachers' beliefs about biotechnology and biotechnology teaching.
2	Technology teachers' belief about biotechnology and its instruction in South Korea	Kwon & Chang (2009)	Investigate Korean technology teachers' beliefs related to imple-mentation of biotech-nology instruction.

Fonseca et al. (2012) found that teachers over-estimated the obstacles presented in biotechnology teaching, particularly concerning material and resource limitations. They demanded the improvement of their information management skills. It was suggested that there was a need to improve teachers' competencies in searching, selecting and adapting information for classroom instruction in the context of biotechnology teaching. Hence teacher training programs should be developed and implemented as part of teachers' preservice and inservice education. Beside that, more complex interventions needed to instruct teachers to adapt those resources according to the specificities of their students and schools should be organized at national level.

Kwon and Chang (2009) who conducted research on 114 Korean middle school technology teachers stated that the teachers' beliefs were measured in three domains that are value, expectancy and innovation. The results indicate that their beliefs were significantly associated with teacher intent to teach biotechnology content in their classes. This study recommends that biotechnology content should be delivered systematically to technology teachers through professional

development (i.e., in-service and pre-service training).

4 Educational implications

Biotechnology is an area which is still undergoing evolution and new discoveries are reported abundantly. Linking to this phenomenon, the school children need to be equipped with the knowledge of biotechnology. Students need to be aware of the advantages and disadvantages of biotechnology to humankind. As teachers, they have to be well versed with the knowledge, the method and approach of teaching biotechnology. Only then will we be able to inculcate the right decisions and inform citizens of the future generation.

From the articles analysed related to teachers and students, we concluded that there is a lot of room for improvement. In the perspective of students, their understanding about biotechnology terms and concept was still low. They were still confused with the basic knowledge about biotechnology. The attitudes, the sets of values and ethics which the student held were varied as shown in the reports from the papers published in the journals used in this study. The argumentation, decision making and debating strategies the students implemented were not consistent with the goal of scientific literacy. This may be due to the lack of understanding the student had and insufficient debating skills thus making it difficult for them to produce constructive and a meaningful debate.

Looking at the angle of teachers, they seem to have difficulties in conveying the teaching of biotechnology to the students. Both the pre-service and the in-service teachers showed that they lacked the opportunity to undertake biotechnology teaching because the concept was quite abstract. The resources in school were not making it happen because the laboratory equipment needed was very limited and it required a well equiped laboratory to teach teach concepts. Beside that, the teachers seemed to be unsure about the best techniques to teach concepts. They were looking around to find ways to make their teaching more meaningful.

The following are our recommendations for helping to improve the teaching and learning of biotechnology in education:

i) Research on other related areas should be carried out. How students understand and how they transfer the knowledge they gather from the learning of biotechnology related topics to solving problems and issues in their daily lives deserve further investigation. It will help us to really understand how they think and learn, how they assimilate and accommodate new knowledge into their existing schemata. Research on metacognitive aspect of the students is another kind of research that can be considered. This will give some understanding on how the students use particular strategies for learning or problem solving or how they are aware about their metacognition.

ii) The in-service teachers need to be given more exposure to the new and current advances in biotecnology so that they will have confidence and could teach the students using the new knowledge acquired.

iii) Schools should collaborate with universities or any other biotechnology-related agencies so that the students can have an opportunity to at least see in reality how biotechnologists work and come up with their findings.

iv) Teacher training colleges or universities involved in preparing pre-service teachers should incorporate biotechnology courses in their curriculum. This will give the teachers a feel of biotechnology activities and experiments so that they can pass the knowledge with confidence to their students.

v) The curriculum board should revise and improvise the existing teacher training and school curriculum. The limitations found must be addressed in a better manner to achieve the vision of having a scientifically literate citizen in the 21st century.

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