Exploring grade 9 learners' knowledge of and attitudes towards biotechnology in two South African Schools

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DECLARATION

I declare that this research report is my own unaided work, except as indicated in the acknowledgements, the text and the references. It is being submitted in partial fulfilment of the requirements for the degree of Master of Science at the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other institute.

signed on _29th__ day of _May_ 2015

Tanuja Sewsunker

ABSTRACT

This research was motivated by the necessity for Biotechnology education in the General Education and Training (GET) phase as biotechnology influences our daily lives in almost every way. Our human population is continually increasing and there is a need for increased food security to sustain the larger population. Hence technological advancement in the medical, agricultural and commercial sectors are taking place every day. Therefore, biotechnology education is necessary at an early age in order for learners to make an informed decision about the different products that are available in the market.

This qualitative study aimed to identify the knowledge of and attitude towards biotechnology among grade 9 learners. This study was conducted in two South African schools in the Gauteng province. A total of 360 learners participated in the study and 25 learners from each school were selected as the sample for the study.

Data was gathered using a questionnaire which consisted of closed ended and open ended questions based on knowledge and attitudes. The data analysis was essentially qualitative as it involved interpretation of the learners' response in order to gain further understanding and insight. However, part of the questionnaire i.e. question 2 was quantitative. The data analysis revealed that grade 9 learners do indeed have knowledge about biotechnology. However, some of the knowledge they have, has many misconceptions i.e. in terms of genetic modification, inserting or removing genes and this largely due to a lack of formal teaching, as it is not a requirement in the grade 9 Natural Science curriculum.

This information is useful for teachers teaching Natural Science and for teachers teaching Life Sciences to grade 10, 11 and 12, as well as curriculum developers.

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DEDICATION

I dedicate this research report to my husband Rakesh Sewsunker and my children Yadav Sewsunker and Deetya Sewsunker whose continual support, encouragement love and belief in my potential sustained me.

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CHAPTER ONE

An introduction to the study and its context

1.1 OVERVIEW OF THE STUDY

This study investigated grade 9 learners' knowledge of and attitudes towards biotechnology. This chapter describes and explains the context of the study, and the specific problem that motivated the study. The aim of the study was to determine if grade 9 learners have prior knowledge of biotechnology and the attitudes these learners have based on their knowledge of biotechnology.

1.2 INTRODUCTION

Biotechnology! Biotechnology! Biotechnology! It seems like this has become the buzzword from research institutions to commercial industries and is now more prevalent in many Science and Technology classrooms worldwide. The term biotechnology was first used by a Hungarian engineer, Karl Erkey in 1919 (Verma, Agarhari, Rastogi & Singh, 2011). Biotechnology applications were practiced long before the term could be coined. Ancient and traditional practices in biotechnology date back to 500 BC (see the history of the development of biotechnology in Appendix 2). With advancements in science and technology and the discovery of the cell, biotechnology has gained even more importance as scientists are able to investigate and improve medical technology, agricultural and commercial products.

The rapid growth of biotechnology knowledge during the past decades has made it necessary to rethink the content of the school science curriculum (Kidman, 2009). The process of modern biotechnology such as genetic engineering, cloning and the use of micro-organisms increasingly impact on society and our daily lives. It is important that learners have a well developed scientific understanding of biotechnology and its associated processes, so that they may effectively participate in public debates about ethical issues related to the use of biotechnology or benefit from its other positive contributions to society.

In South Africa, the concept of biotechnology was formally introduced in the Life Sciences curriculum for the first time in 2006 in the Further Education and Training (FET) phase of schooling (Department of Basic Education, 2006). Studies related to the learners' understanding of biotechnology applications and products thereof have been conducted in Australia and New Zealand by Kidman (2009), in Turkey by Usak, Erdogan, Prokop & Ozel (2008), in the Netherlands by Klop & Severiens (2007) and in Taiwan and the United Kingdom (UK) by Chen & Raffan (1999). In South Africa, the majority of the studies related to biotechnology emphasise consumer studies. A South African study that was used in this study to highlight misconceptions, focused on biotechnology in terms of genetic engineering, which included genetics and inheritance of characteristics (Sebitosi, 2007).

1.3 BACKGROUND TO THE STUDY

1.3.1 All about Biotechnology

When the Sumerians brewed beer in 1750 BC, they did not know about yeast, genes and DNA. Today, using recombinant DNA technology, biotechnologists can breed new strains of brewing yeast to improve the quality of beer (Ackerly, 2011). Biotechnology is a wide-ranging practical field that involves the application of Science and Technology to living organisms. Later, scientists described biotechnology as an application of the principle of engineering and biological science to create new products from raw materials of biological origin, e.g. vaccines and food. Biotechnology is also described as the use of living organism/s or their product/s to modify or improve human health and the human environment (Ackerly, 2011). Biotechnology applications are widely used in the pharmaceutical, agricultural and commercial industries. The applications of biotechnology are limited only to the extent of the human mind.

However, with biotechnology practices come many ethical issues or concerns. These issues pertain to the role of genetic modification in relation to human health, food safety, security and consumer choices, as well as environmental issues relating to biodiversity of fauna and flora. Society at large needs to be aware of the changes brought about by applications in biotechnology and the impact and influence of these changes in our daily lives. Therefore it is

important that Science curricula include biotechnology education so that learners can make informed decisions about biotechnology products.

1.3.2 Biotechnology in the South African Life Sciences Curriculum

The development of Biotechnology by the South African government has been well recognised (Webster & Akanbi, 2005). According to a report compiled by the National Biotechnology Strategy for South Africa, South Africa is one of the few countries in Africa that has commercial production of genetically modified (GM) foods or crops (on a much lower scale than China), (Parker, 2001). Parker claims that biotechnology could play a very important part in African globalisation with South Africa as a leader and at the centre of training and innovation.

In another study to determine public understanding and knowledge of GM foods, it was found that only 27,4% of South Africans felt somewhat familiar with the term 'genetically modified' and a mere 7% thought they knew what it was and would be able to explain it to a friend (Joubert, 2001). However, this study also found that more than 40% of respondents with a tertiary education were somewhat familiar with the term, while close to 20% of those with a tertiary education understood the term well enough to explain it to someone else. Biotechnology as a discipline in science is offered at many tertiary institutions; University of the Witwatersrand, University of Johannesburg, University of Kwa Zulu Natal and many more in South Africa. Food technology also incorporates biotechnology in the hospitality courses offered at tertiary institutions.

In order to meet the global competitive trends and demands of Science and Technology, South Africa's Life Sciences curriculum had to be revised and has gone through several transitional phases aimed at, among other changes, incorporating biotechnology (Department of Basic Education, 2006). Hospitality courses that are offered at some Further Education and Training (FET) schools also incorporate biotechnology in their curriculum specifically with respect to food technology and food security (Department of Basic Education, 2003). In the General Education and Training (GET) phase, in the grade 8 Technology curriculum, biotechnology is discussed in terms of preserving and pickling foods and in the grade 9 Natural Sciences curriculum, biotechnology is discussed in terms of career choices related to biotechnology.

With rapid growth and advancement in biotechnology and the impact it has on our daily lives, various studies show that it is imperative to educate our learners from a younger age to be informed citizens so that the necessary and appropriate decisions can be made (Kidman, 2009; Joubert, 2001; Chen & Raffan, 1999).

1.4 RATIONALE

Research based on the knowledge of and attitudes towards biotechnology among learners between the ages of 12 to 18 years has been carried out and documented in Taiwan and the UK by Chen & Raffan (1999) and in Australia by Dawson (2006) and Kidman (2009). In South Africa the majority of the studies on biotechnology are done on consumer studies. The target group of biotechnology research in South Africa is mainly the adult population and there is very limited research and interest focused on the knowledge and views of secondary school learners (Donninger, 2006). Prokop, Leskova, Kubiatko, & Diran, (2007) emphasised that research involving investigations of knowledge and attitudes towards biotechnology among school-age learners is a limited and relatively untapped area. Therefore the rationale for this study is two-fold:

Firstly, learners are exposed to masses of information about biotechnology on a daily basis due to their interaction with the media, activities at school as well as activities in their homes. Since the concept of biotechnology has been formally introduced in the Life Sciences curriculum for the first time in 2006, in grade 10 during their formal schooling, it is important from an educational perspective to determine what existing knowledge grade 9 learners have about biotechnology. Secondly, since knowledge influences attitudes, it is also necessary to find out what attitudes learners have about biotechnology and its influence in the decisions made about the use of its applications in everyday life.

The data generated from this study could serve as useful information to support or assist grade 10 Life Sciences educators in their approach to teaching the concept of biotechnology and related issues.

1.5 PURPOSE OF THE STUDY AND RESEARCH QUESTIONS

The purpose of this study is to investigate what knowledge grade 9 learners have about biotechnology. This study also aims to find out what attitudes have been conceived in relation to the use of biotechnological processes in everyday life.

Therefore the research questions that guided this study are:

(i) What existing knowledge do grade 9 Natural Sciences learners have about biotechnology?

(ii) What are the attitudes of grade 9 Natural Sciences learners towards biotechnology?

1.6 IMPORTANCE OF THE STUDY:

It is hoped that the findings of this study, which is essentially exploratory in nature will provide useful data to inform the design of further research which may examine high school learners' understanding, knowledge and attitudes about biotechnology and subsequently improve biotechnology education.

1.7 CONCEPTUAL FRAMEWORK FOR THE STUDY

A conceptual framework possesses ontological, epistemological, and methodological assumptions and each concept within a conceptual framework plays an ontological or epistemological role. The ontological assumptions relate knowledge of the "ways things are", "the nature of reality", "real" existence and "real" action (Guba & Lincoln, 1994, p. 108). No matter what teachers teach, a teacher always faces the challenge of bringing learners from the point of what they currently know to the point of trying to fit what they have learnt into what already exists. Even though learners may have no experience in your class or field of study, they enter your classroom with a long history of academic training and life experience (Mc Conigal, 2005). Learners need to be able to recognise the limitations of their existing

knowledge and perspectives. When learners learn new information they must be able to assimilate it into their existing knowledge structures.

This study involves finding out about the knowledge that the learners have about biotechnology, therefore the conceptual framework underpinning this study lies in Ausubel's theory of subsumption (Ausubel, Novak & Hanesian, 1978). Ausubel refers to this theory as a process of linking new information to pre-existing ideas. The aim of the conceptual framework in this study is to provide an understanding of the importance of the knowledge that learners have and bring to class about biotechnology and its related concepts.

1.8 ORGANISATION OF THE RESEARCH REPORT

This research report is divided into five chapters. Chapter one describes the context of the study by providing background information to biotechnology and the extent to which the content of biotechnology is addressed in the South African curriculum. A description of the problem that motivated this study and the questions that guided this research are also provided. This chapter also provides the reader with a rationale for the study being conducted among grade 9 learners.

Chapter two provides the conceptual framework underpinning this research, which assisted me in making sense of the information obtained in the study and a review of literature that drew from constructivism focusing on the knowledge of and attitudes towards biotechnology among learners. The emphasis in the literature review is on learners' prior knowledge of and attitudes to biotechnology.

In chapter three a description of the methods used in conducting this study and the reasons for my choice are given. Issues of rigour and ethics in research are discussed in this chapter. This chapter also provides information on the participants and their schools to enhance the readers understanding of the report.

Chapter four provides a detailed description and analysis of the results obtained. The results are discussed in themes that represent the two research questions being answered. The chapter begins with a description of how the data was analysed and the results of the data are captured in graphs and tables.

The final chapter emphasises the summary of findings, limitations of the study as I have reflected upon them, and some recommendations and suggestions for the various stakeholders for future research.

1.9 CONCLUDING REMARKS

The purpose of this chapter was to provide an argument motivating the study, grounded on a literature review to back up the claims made. Biotechnology is a relatively new concept and it presents many controversial issues to our society. Finding out what pre-existing ideas learners hold will afford educators the opportunity to structure their lessons appropriately and enhance the learners' learning process as well as provide them with the necessary tools and skills to understand their encounters with biotechnology in everyday life. The conceptual framework used to understand the learners' knowledge needs and importance of biotechnology will be discussed in the next chapter.

CHAPTER TWO

Conceptual Framework and Literature Review

2.1 INTRODUCTION

"Science is a wonderful way of understanding the world. The last few hundred years have seen tremendous growth in scientific knowledge and this has allowed new technologies to be developed" (Reiss, 2006 p. 123). The rapid growth of biotechnology knowledge during the past decades has made it necessary to rethink the content of the school science curriculum (Kidman, 2009). Learners need to be made aware of the various technological advancements and their applications. The process of modern biotechnology such as genetical engineering, cloning and the use of micro-organisms increasingly impact on society and our daily lives. It is important that learners have a well-developed scientific understanding of biotechnology and its associated processes.

In addition, there have been many public debates around biotechnology and many ethical issues have been raised. A good scientific understanding of biotechnology will enable learners to effectively participate in the controversies surrounding the applications of biotechnology, its benefits and its contributions to improving the quality of life.

This chapter begins with a discussion on the concept of biotechnology, followed by the history of the development of biotechnology, including the science and knowledge of biotechnology. This chapter also focuses on the Life Sciences curriculum in South Africa pertaining to grade 9 Natural Sciences learners, making reference to the importance and relevance of teaching biotechnology at an early stage rather than later on in the grades that follow. This chapter also provides a detailed discussion of the conceptual framework underpinning this study relating it to the knowledge of and attitudes towards biotechnology.

2.2 BIOTECHNOLOGY 'FRIEND OR FOE'

Biotechnology is the use of biological processes to make useful products that assist humans in providing solutions to medical research, industry (cheese and beer making) or agriculture (food shortage). "Bio" in biotechnology represents the science of all living things, and "technology" represents the tools and techniques used to apply our knowledge so that living things can respond as scientists want them to (Donninger, 2006). Biotechnology is a branch of science where living organisms and their products are used for the production of food, drink, medicine or for other benefits to humans, or other animal species (Donninger, 2006). Donninger points out that biotechnology is not a new concept as humans began using biological processes to grow crops and breed animals over 10 000 years ago. Biotechnology has been widely acknowledged as a modern tool that holds a lot of potential in improving three main areas of focus, i.e. its application in agricultural production, medicine and medical research and in the commercial industry.

In agriculture, for example, biotechnology in the form of genetic engineering is a precise way of developing seeds with special qualities such as producing a crop that is resistant to a particular disease. As our knowledge of genetics has improved we have used this knowledge to selectively breed organisms. This has resulted in organisms with favourable characteristics and improved agricultural yields (Donninger, 2006).

In the pharmaceutical industry, new biotechnological applications have enabled the production of many vaccines from micro-organisms to treat various diseases. Another very important development or advancement in medical research is the discovery of antibiotics by Alexander Fleming in 1929. The penicillin production process was the first biotech process to be implemented in the pharmaceutical industry (Brakhage, 2004). Since then the importance of antibiotics has grown and today over 8000 antibiotics are known. Antibiotics are chemical substances that are produced by micro-organisms and they are effective in destroying bacterial diseases. In addition antibiotics help the human body to build its immunity during viral infections by stimulating the release of antibodies to inhibit further infection. The topic on micro-organisms is discussed in grade 11. The production of the antibiotic Penicillin from *Penicillium notatum* is discussed in grade 11 in terms of biotechnology processes.

In the chemical industry techniques of modern biotechnology have been used to reduce the impact of manufacturing and the effects of global warming on our environment (Donninger, 2006). In the commercial industry, micro-organisms such as yeast are used for the production of beer and bread, and bacteria are used for the production of cheese. The practice of traditional biotechnology has provided the principle for large scale present day use of the processes of biotechnology in the industry. The topic on micro-organisms and traditional biotechnology is discussed in detail in the grade 11 Life Sciences curriculum. The grade 11 curriculum focuses on traditional biotechnology in terms of the production of cheese, bread and beer on a commercial level (see Appendix 3). Cloning, genetic modification, and reproductive therapy are other examples of biotechnology which are also part of the grade 10 Life Sciences curriculum (see Appendix 3).

However, although there may be many benefits of the processes and products of biotechnology, there are many concerns that exist as well. Many consumers question the fact that side effects may result from consumption of the products and as a result have a very negative attitude towards biotechnology. Educating learners about biotechnology is therefore important in order for them to make informed decisions about the various products available in our daily lives.

2.3 HISTORY OF THE DEVELOPMENT OF BIOTECHNOLOGY

Biotechnology as a concept in science teaching has gained increasing importance over the last few years as it is directly related to activities in our daily lives. The earliest use of biotechnology dates back to 500 BC when the Chinese used mouldy curds as an antibiotic to treat boils and the Greeks practiced crop rotation to increase soil fertility and enhance the yields of their crop (The history of biotechnology – Appendix 2). Since the work of Watson and Crick in the mid 1950's, knowledge about cells and genes had increased and scientists were able to use the smallest parts of cells i.e. DNA, in addition to using the entire organism for medical research and science (Chattopadhayay, 2005). Early practices in biotechnology include planting of crops and breeding animals. Greater interest in biotechnology prompted further investigations by scientists who later discovered fruit juices fermented into wine,

cow's milk could be processed into cheese and beer and bread could be made by using yeast cells.

Many key discoveries in the history of the development of biotechnology can be highlighted. During the pre- 20th century period, there was a great interest in cells due to the invention of the microscope. Further scientific observations led to the discovery of DNA, which is the building block of genes. By the 1980's scientific investigation in biotechnology had reached new heights with the development of the first genetically engineered vaccine for the treatment of cancer (Donninger, 2006).

2.4 SCIENCE BEHIND BIOTECHNOLOGY

All biotechnology is based on the science or biological functioning of the organisms. All organisms are made up of the basic units of life which we refer to as cells. The nucleus is a structural part of cell which contains DNA in chromosomes. The information encoded on the DNA strand is used by cells to determine the characteristics and functioning of the cell (Calladine, Drew, Luisi & Travers, 2004). A portion of the DNA strand i.e. the gene is used and manipulated to bring about desired favourable characteristics in genetically modified organisms. The study of this small DNA strand which carries the essential "code of life" has enabled scientists to enter a different dimension of possibilities in genetics, biomedical science, agriculture and commercial industry.

Current trends in biotechnology research have enabled scientists to create skin tissue from stem cells to assist burn victims. Cloning, a process of making an exact replica of an organism has enabled farmers to increase the production of milk. This is achieved by removing the ovum of cow A through surgery. The nucleus is then removed using micro-surgery in the laboratory. This nucleus is removed as it has half the number of chromosomes as compared to a somatic cell. A somatic cell is then removed from cow B (increased milk production). The nucleus of the somatic cell is removed and inserted into the ovum of cow A. The ovum now has a diploid number of chromosomes and behaves like a fertilised egg. This ovum is then attached to the uterus of cow A and undergoes cell division resulting in an offspring which is identical to cow B. An example of this process was conducted in Brits

(Johannesburg) in 2003 and the offspring was champion milk producer Futhi, who produced at least 78 litres of milk per day (Isaac, Chetty, Manganya, Mpondwana & White, 2013). Appendix 2 shows a timeline of further advancements and trends in the development of biotechnology over the years.

2.5 KNOWLEDGE ABOUT BIOTECHNOLOGY

One of the most essential outcomes of science education is to enable learners to have a critical view and a deeper understanding of the world around them (Dawson, 2006). When a learner has a deeper understanding and a high level of scientific literacy, he or she is able to question and challenge the claims made by the larger scientific community.

Young people are exposed to volumes of biotechnology applications and information on a daily basis. Sometimes the existing knowledge that young people have, may be conflicting with the information they may encounter in their everyday experiences therefore it is important for young people to be well informed. When young people are well informed about the practical applications of biotechnology, they are able to appreciate the social and ethical implications and make wise decisions when contributing to public debate in the future (Dawson & Schibeci, 2003).

The most important aspect of a modern science curriculum is for learners to develop a sound scientific understanding of concepts taught and developed by the science teacher. Biotechnology is a concept that has evolved over the last 25 – 30 years into a powerful set of tools used in many sectors such as medicine, agriculture and genetic engineering (Webster & Akanbi, 2005). Biotechnology is "a body of knowledge" that needs to be understood so that learners can make the necessary link or connections among cells, genes, chromosomes and DNA to biotechnological processes such as genetic engineering, cloning and the use of micro-organisms to improve human health.

In South Africa, many of the biotechnology studies show concern about consumer understanding and the bio-economy. According to Donninger (2006), adults between the ages of 20 to 40 years respond differently towards biotechnology processes. The findings of this study show that while 40% of these adults respond positively to the use of genetically modified products, 48% respond negatively and a further 13.4% are undecided about

biotechnology applications. According to Dawson & Schibeci (2003), prior to their study in Australia, there was no published Australian literature on understandings and attitudes of school learners about biotechnology. Much of the research that was conducted was based on teachers' perceptions.

Hofer & Pintrich (1997) emphasise that science educators and researchers have been interested in "how individuals come to know, the theories they hold about knowing, and the manner in which such epistemological beliefs are a part of and influence the cognitive processes of reasoning and thinking." It is important for educators to determine what knowledge learners' hold about biotechnology or related concepts as it provides them with valuable information on an appropriate approach to teaching. There are various factors that influence a learner's construction of knowledge. These factors include contextual situation, social interaction, prior teaching and media. Chen & Raffan (1999) in their study clearly indicate that the contextual situation and social interaction are influential in the construction of knowledge. Their study makes reference to the United Kingdom (UK) encouraging debates about biotechnology while in Taiwan teachers do not encourage such controversial issues. It is the context and social interaction that influence the construction of knowledge and the manner in which a learner may react to a situation or accept or disapprove of a certain application (Chen & Raffan, 1999). It is therefore important that the researcher identifies whether or not a link between knowledge and attitudes exists. It is also a basic tenet of constructivism that what's on the child's mind matters so that the teacher can identify misconceptions and restructure these with a view to restoring the scientifically acceptable viewpoint in science.

Several other studies about the knowledge of and attitudes of learners towards biotechnology have been conducted in various countries such as Australia, New Zealand, Slovakia, Netherlands, UK and Taiwan (Kidman, 2009; Klop & Severiens, 2007; Prokop et al., 2007; Dawson, 2006; Chen & Raffan, 1999). These studies indicate what understanding the learners have about biotechnology as well as highlight some of the misconceptions that exist. The research findings reveal that there is a link between knowledge of and attitudes towards biotechnology. From the above mentioned studies one can also identify the trend that attitudes tend to change as the learners become more aware of their knowledge about biotechnology.

Dawson (2006) and Chen & Raffan (1999) carried out investigations about the knowledge of and attitudes towards biotechnology among learners between the ages of 12-18 years. Dawson's (2006) cross sectional study of grade 8, 10 and 12 learners reveal that they were able to provide generally acceptable definitions of biotechnology, cloning and genetically modified foods. However, this study also indicates that although learners in general were able to provide the definitions, learners between the ages of 12 and 13 years (usually grade 8) had a relatively poor knowledge of biotechnology as compared to the older learners. These are examples of some of the definitions expressed by 12-13 year olds i.e. "biotechnology is the use of living organisms to produce useful products", while cloning was defined as "making a genetically identical copy" and genetically modified food as "a food where the DNA has been changed" (Dawson, 2006, p. 65). Dawson (2006) attributes this finding to the lack of formal instruction about genes, genetics and genetic technology among younger learners.

In 2003, Dawson & Schibeci's study indicated that from a study of 1116 learners between the ages of 15 – 16 years, approximately one third of the learners had little or no understanding of biotechnology and were therefore unable to provide an example of biotechnology. Learners were unable to distinguish between current and potential uses of biotechnology and were confused about the difference between cloning and genetic engineering as well as between genetically modified foods and foods produced through selective breeding (Dawson & Schibeci, 2003).

In another study related to the understanding of genetics and inheritance in rural schools, in two provinces of South Africa, the analysis of data reveals that learners between the ages of 15-16 years hold many alternative conceptions of the concepts 'cells, genes, genetically modified organism' and 'cloning'. (Sebitosi, 2007). A concept map was the research instrument used in this study, revealing many misconceptions about concepts such as genes and chromosomes as well as conflict between traditional beliefs and scientific reasoning (Sebitosi, 2007). One of the misconceptions that were highlighted relates to traditional beliefs about albinos. Sebitosi's study (2007) claims that, in the past learners were told by elders that killing an albino child brings an albino child. According to this study it therefore seems like albino babies were killed as newborns and buried under the family house. This has important implications for learning and teaching and therefore the influence of local beliefs cannot be ignored. The implication here is that learners bring into the classroom prior knowledge which

should be identified before scientific concepts relating to genetics and inheritance are taught. This is in line with Ausubel (1968) who advocates that a teacher must ascertain what a child already knows before teaching.

The results discussed by Sebitosi (2007) indicate that there is a gap in the South African Life Sciences curriculum as cells are taught in grade 9 and learners are unable to make the link between cells, genes and chromosomes when genetics is taught later in the curriculum at a higher level. Her study also shows that lack of association and understanding makes it difficult to relate concepts and processes at different levels of organisation.

Lock (2007) also conducted an investigation of knowledge and attitudes towards biotechnology among 14-15 year old learners in England, 112 of whom were males and 76 were females. In this study two sets of questionnaires and a teaching intervention session based on biotechnology were used in the data collection process. Lock, upon analysis of the data, concluded that the learners' knowledge of biotechnology increased due to intervention and their attitudes were more positive. Similarly, Dawson & Schibeci (2004) also found that in Australian schools a greater awareness of biotechnology resulted in a more positive attitude towards biotechnology applications and processes.

Dawson's study (2006) indicates that older learners have a better understanding of biotechnology while the findings of Chen & Raffan (1999) show that learners between the ages of 17-18 years in Taiwan and the UK had limited knowledge of the concept of biotechnology. Their study indicated that only 50% of the participants in both countries were able to give examples of biotechnology. This study also noted some differences in the learners' knowledge as Taiwan learners were unable to provide definitions of cloning, genetic engineering, biotechnology and genetically modified foods. The UK has a comprehensive coverage of biotechnology in their science curriculum in comparison to Taiwan. Apart from the curriculum coverage of biotechnology in both countries, there is a difference in the manner in which their learners are encouraged to participate in controversial issues surrounding the topic (Chen & Raffan, 1999) i.e. the UK has an extensive curriculum for biotechnology and are able to explore the different aspects while the Taiwan curriculum is limited and therefore lack extensive information to encourage learners to openly discuss issues related to biotechnology.

Studies conducted by Armstrong & Weber (1991) and Dawson (2006) indicate conflicting findings on whether an increased understanding of biotechnology results in a change of learners' attitudes to the use of biotechnology. However there is evidence that introducing learners to biotechnology will improve understanding and decrease levels of uncertainty.

2.6 BIOTECHNOLOGY IN THE SOUTH AFRICAN LIFE SCIENCES CURRICULUM

The South African government has recognised the existence of biotechnology and the role that knowledge of this concept can play in improving the health, welfare and quality of life of the citizens of the country (Webster & Akanbi, 2005). Webster & Akanbi report that the government has developed a strategy for the development of the biotechnology industry and has been involved in research and development for over 30 years. In order to meet the global competitive trends and demands of Science and Technology, South Africa's Life Sciences curriculum had to be revised and has gone through several transitional phases aimed at, among other changes, incorporating biotechnology.

The concept of biotechnology was included as a topic in the Life Sciences curriculum of the revised National Curriculum Statement (NCS) in 2006, in the Further Education and Training (FET) phase. Biotechnology was formally introduced to grade 10 Life Science learners for the first time in 2006. Topics such as traditional biotechnology related to indigenous knowledge and stem cell research was introduced. The NCS Life Sciences curriculum has undergone further review resulting in the present Curriculum and Assessment Policy Statement (CAPS) which was implemented in 2012 for grade 10. Appendix 3 indicates the extent to which the concept of biotechnology is addressed in each grade of the FET phase (Department of Basic Education, 2012a).

However, the CAPS document for the grade 9 Natural Sciences Life and Living strand addresses the concept of biotechnology in terms of career guidance as per specific aim 3.3 in terms of; *the value and application of Natural Sciences knowledge in industry, in respect of career opportunities and in everyday life, e.g. Palaeontology, agriculture, biotechnology and genetic engineering* (Department of Basic Education, 2012b, p 63). The CAPS document for Natural Sciences for grade 9 also states that concepts and careers related to biotechnology should not be discussed in detail (Department of Basic Education, 2012b).

Since grade 9 learners are being made aware of biotechnology prior to its introduction as a topic in the FET phase, it is important to identify what knowledge they have about biotechnology and its use in their daily lives. Finding out what biotechnology concepts have been constructed by grade 9 learners is important as it will create a link to the FET phase and inform the Life Sciences educators' understanding of how to approach the teaching of biotechnology. Creating awareness as well as informing learners about biotechnology is essential as it enables them to identify applications of this discipline in the various fields of Science and thereby make more informed decisions.

2.7 ATTITUDES TOWARDS BIOTECHNOLOGY

An attitude according to Ajzen & Fishbein (1980) is defined as a person's intention, subsequent behaviour and decisions about an object or issue. An individual has knowledge and beliefs about concepts or objects that lead to an attitude or perception about them (Barmby, Kind & Jones, 2008). Hence, in the context of biotechnology, it is the knowledge component related to the existing attitude component that may lead to the informed decisions or actions about a specific issue.

Dawson's study (2006) of Australian learners between the ages of 12-18 also highlights a wide range of attitudes about what is acceptable and what is not. More than 90% of the learners approved of the use of micro-organisms for specific biotechnology processes such as beer and cheese making. Studies by Chen & Raffan (1999) and Dawson (2006) study show that learners support genetic modification of plants but they are not in favour of the use of animals in biotechnology processes. The learners' attitudes were therefore that biotechnology is acceptable in plants but not in animals. Chen & Raffan (1999) also indicated that learners studying A-level Biology had a more positive attitude towards biotechnology than those not studying Biology.

It is evident from the various studies discussed earlier that the existing knowledge of a learner plays a very important role in determining attitudes and meaningful learning.

2.8 CONCEPTUAL FRAMEWORK

The single most important factor influencing learning is what the learner already knows: ascertain this and teach him accordingly (Ausubel, 1968 cited in Sebitosi, 2007, p56).

In view of the above statement and with respect to the research questions that this study aims to address, the conceptual framework underpinning this study lies in Ausubel's theory of subsumption (Ausubel, Novak & Hanesian, 1978). The process of linking new information to pre-existing ideas is referred to as subsumption (Ausubel et al., 1978). Ausubel (1968), a cognitive constructivist theorist, advanced a theory which contrasted meaningful learning from rote learning. In Ausubel's view, meaningful learning involves recognition of the links between concepts. The crucial focus in meaningful learning is how the new information is integrated into the old knowledge structure. Ausubel also believes that knowledge is hierarchically organised i.e. new information is meaningful to the extent that it can be related or anchored to what is already known. Apart from Ausubel, two other prominent cognitive constructivist theorists, Jean Piaget and Lev Vygotsky have also been highly influential in understanding the process of human learning. Piaget emphasises the individual's active construction of understanding (Piaget 1964, 2003).

2.8.1 Concept Learning and Propositional Learning

Concepts form an integral part of assimilation theory because comprehension and meaningful problem solving depend on the availability of existing ideas or anchoring concepts of the learner's cognitive structure. The link between subsumption and assimilation lies in the integration of new information with what the learner already knows i.e. the learner must be able to recognise what new information is presented to him /her and how this information fits in or can be integrated into the existing cognitive structure. The ability of the learner to formulate a new concept and assimilate it into their existing conceptual framework will facilitate meaningful learning. With respect to cognitive structure human beings interpret their 'raw' perceptual experience of everyday interactions in their environment in terms of particular concepts and it is these concepts that constitute the building blocks for meaningful learning of propositions (new ideas expressed as schemes) and for the generation of problem-solving propositions (Ausubel et al., 1978). Meaningful learning therefore involves the acquisition of new meanings, and new meanings are conversely the products of meaningful

learning (Ausubel et al., 1978). Thus information or a related concept that has meaning is stored in networks of connected facts or concepts, which Ausubel referred to as schemata.

The diagram below indicates the process leading to meaningful learning.

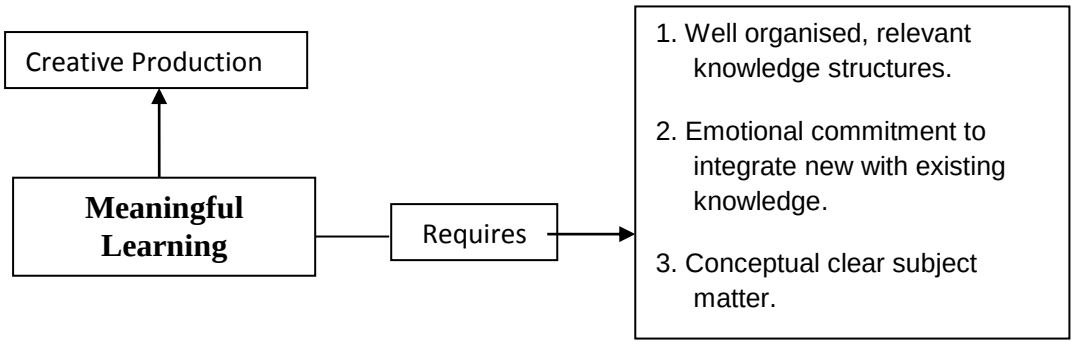


Figure 2.1: Requirements for integration of new information and meaningful learning.

Ausubel et al. (1978) also make reference to propositional learning which emphasises the differentiated cognitive content that has resulted from the meaningful process which can be related to the content of the relevant existing ideas that have been established in the cognitive structure of the learner.

2.8.2 Anchorage of new information to existing ideas

It is important to understand that meaningful learning does not mean that there is an immediate link of new information to pre-existing ideas of the cognitive structure. On the contrary simple linkage of information can be applied to rote learning. When an individual acquires new information through learning, both the newly acquired information and the related relevant concepts of the cognitive structure undergo modification in order to create a link. In order to show that meaningful learning involves an interaction between new information and pre-existing ideas in the cognitive structure, Ausubel et al. (1978), refer to this process as anchorage.

Hence, in both concept learning and propositional learning new information is frequently anchored to relevant aspects of an individual's existing cognitive structure. This process of

linking new information to pre-existing ideas and making a connection with the existing cognitive structure is referred to as subsumption (Ausubel, 1968). The efficiency of subsumptive learning, according to Ausubel, can be attributed to the fact that once an idea is adequately established in the cognitive structure it has specific and direct relevance for subsequent learning tasks. The idea established in the cognitive structure also possesses sufficient inherent stability to provide the firmest type of anchorage of the newly learned detailed meanings. These ideas that have been developed also organise related new facts around a common theme, thereby integrating the component elements of the new knowledge both with each other and with prior knowledge (Ausubel et al. 1978).

Anchorage, therefore, appears to play an important role in the assimilation and integration of new knowledge and hence meaningful learning. In my experience as an educator tapping into what the learner already knows proves to be valuable and imperative as it enables me to establish the learners anchoring concepts and hence prepare material around that information thereby building on the existing concepts. For example yeast, a learner may know that yeast is an ingredient used in the baking of bread but may not know that yeast is a micro-organism and it is a process of fermentation that results in the formation of carbon dioxide that causes the bread to rise. Therefore, identifying what the learner knows plays an important role in developing the existing cognitive structure.

2.9 ATTITUDES

With respect to investigating what learners know about biotechnology it is important to understand what influence their knowledge has on their attitudes towards biotechnology and its application in everyday life. Therefore, psychologists such as Bagozzi & Burnkrant, (1979) and Eagly & Chaiken, (1993) in Prokop et al. (2007) have indicated that attitudes have three components which are important to assess. These components are (1) the cognitive component which refers to the beliefs and knowledge of the objects, (2) the affective component which includes feelings about the use of the object and (3) the behavioural component which pertains to the manner in which people act towards the object.

In many cases, unfortunately, learners' prior knowledge is not always acceptable from a scientific point of view as it includes ideas that have developed through experience and

interaction within their environment. However the underlying knowledge may have resulted from a misconception. From a teaching perspective, the question that most often arises is how to create classroom experiences that encourage development or change in learners' conceptions from their informal ideas that may have resulted from their social interactions to those of accepted school science (Scott, Asoko, Driver & Emberton, 1994). It is the effect or the impact of the new knowledge that influences the learners' attitudes in terms of the cognitive structure, affective and behavioural aspects.

Hence the framework underpinning the study is one of cognitive constructivism in relation to the theory of subsumption which clearly indicates that anchoring concepts influence the assimilation of new ideas into the cognitive structure.

The flow diagram below shows the relationship between existing knowledge and its influence on attitudes.

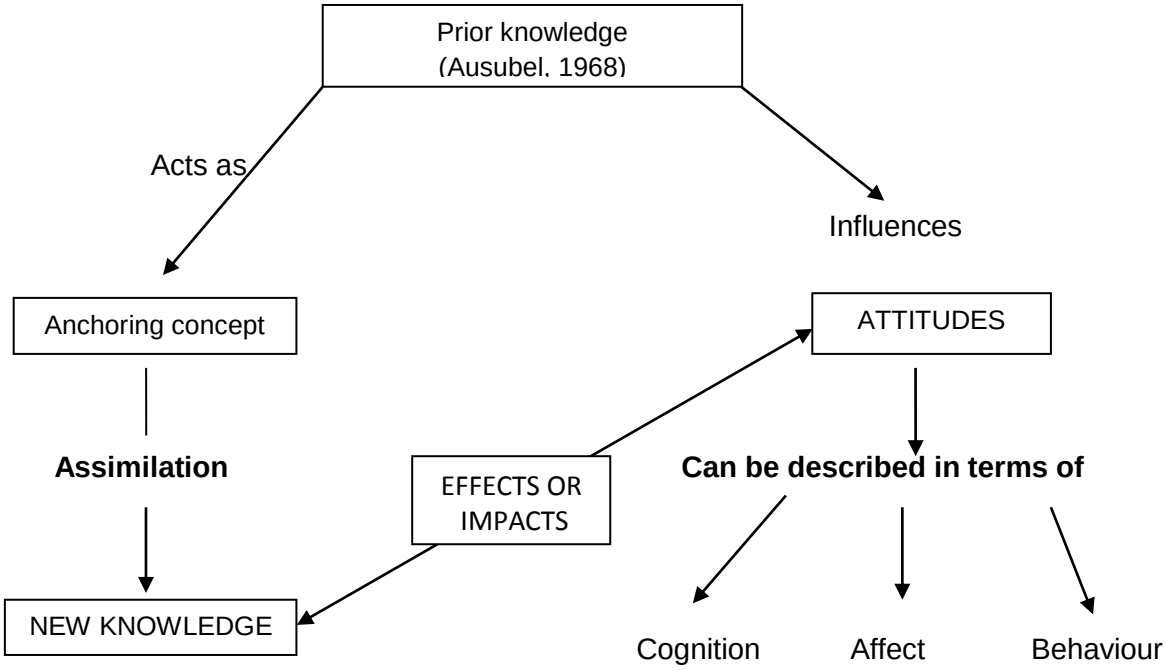


Figure 2.2: Diagrammatic representation of the theory of subsumption and assimilation

2.10 EXPLANATION OF CONCEPTUAL FRAMEWORK

In order for a learner to grasp the concept of cloning as a biotechnology process, prior knowledge on cells, chromosomes, genes and mitosis are necessary as anchoring concepts to assimilate new information about cloning. For example, when learners in grade 9 learn about

the cell, the focus is on the nucleus as the nucleus controls cell division. Therefore learners would first have to understand the parts of the nucleus i.e. chromatin material and chromosomes to understand how cloning is made possible.

2.11 CONCLUDING REMARKS

The theory of subsumption is relevant to my study as it points out the relevance of prior knowledge and how it influences the attitudes of a learner towards the concept of biotechnology. Anchoring concepts play an in important role in the assimilation of new knowledge and understanding and this aspect has helped to structure my research design along the same lines. In the next chapter a detailed description of the research design and methodology will be presented and discussed.

CHAPTER THREE

Research Design and Methodology

3.1 INTRODUCTION

The purpose of this chapter is to describe the research design and the empirical techniques that have been applied in this research. This chapter defines the method followed during the investigation and emphasises the scope and limitations of the research design.

This study entails both qualitative as well as quantitative approaches. These approaches will be discussed in relation to this research study. The data collecting technique used in this study was a questionnaire which consists of open ended questions as well as closed questions. A detailed description of the questionnaire and its development will be discussed. This chapter describes the research design which encompasses the reliability and validity of the research, reasons for selecting the sites for the research, collecting and analysing of data, the pilot study and the selection of the participants as well as the ethics applicable to the study.

3.2 METHODOLOGY

The aim of South Africa's education system is to equip the younger generation with the necessary knowledge, problem solving skills and values to cope with increasing technological advancements in our daily lives (Department of Basic Education, 2012a). This research study investigated the knowledge and attitudes that grade 9 learners have towards biotechnology. Grade 9 learners were chosen for this study as it is the first time they are introduced to the concept of biotechnology. Therefore, this study attempted to find out the pre-existing ideas that grade 9 learners have about biotechnology.

The research method I adopted was a survey. A survey is a type of research design that gathers data at a particular point in time with the intention of describing, identifying and comparing the attitudes, behaviours and characteristics of a population (Cresswell, 2007; Cohen, Manion & Morrison, 2007). As stated by Cresswell (2012), surveys help identify

important beliefs and attitudes of individuals within a population. In terms of this study a survey was adopted as it included the grade 9 population of two schools describing and comparing their understanding, knowledge and attitudes towards biotechnology. There are several characteristics of a survey study, one of which being the ability to gather data in a short space of time and hence it is economical and efficient. It also enables the researcher to present numerical data and material which is uncluttered by specific contextual factors (Cohen et al., 2007). Surveys represent a wide target population and therefore there is a need for sampling. In this study a sample of 25 learners from each school was chosen out of a total target population of 360 learners combined, thus the study was undertaken on a small scale basis and the generalizability is slight (Cohen et al., 2007). Two schools in the Gauteng province were chosen for the investigation. The two schools were representations of different contextual situations, one of which is situated in a suburban area of Midrand while the other is situated in a nearby township area of Tembisa. The context as well as the environment, plays a very important role in the manner in which a learner constructs his or her knowledge. The availability of resources, up to date and current technology also influence understanding and learning. The reason for choosing two different contexts was to make comparison with respect to the responses provided by the learners.

3.2.1 Qualitative study Approach

Merriam (2009) claims that qualitative researchers are interested in understanding the meaning people have constructed, that is, how people make sense of their world and the experience they have in the world. According to Denzin & Lincoln (2005), qualitative research is a situated activity that locates the observer in the world. It consists of a set of interpretive, material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memos to the self. At this level, qualitative research involves an interpretive, naturalistic approach to the world. This means that qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them (Denzin & Lincoln, 2005). The questionnaire was the only instrument that I used to obtain data. The questionnaire was designed such that it enabled the researcher to collect both qualitative and

quantitative data. The question then raised was "Could this possibly be a mixed methods research or is it essentially a qualitative study?"

Denscombe (2007), states that a mixed methods research refers to the combination of alternative approaches within a single research project. Both Johnson & Onwuegbuzie (2004) and Denscombe (2007) make reference to a researcher using a combination of quantitative and qualitative methods of obtaining data. A combination of both qualitative and quantitative approaches provides more comprehensive evidence and a better understanding of research problems than either approach alone. Since the only tool used to collect data was the questionnaire, it is safe to say that it is not a mixed methods research as the questionnaire had requested more knowledge based responses which required interpretation rather that quantitative analysis. Qualitative research is interpretive, focusing on gaining meaning, understanding and building concepts and theories (Miles and Hubeman, 1994). With respect to this research, participants are required to express their ideas about biotechnology by providing reasons to questions when the learner was asked to do so. The reasoning aspect enabled me to gain an insight into whether or not the participant accepts practices in biotechnology.

However this research study does have a component of quantitative data. In contrast to qualitative data, it is argued that quantitative research is weak in understanding the context or setting in which people may interact and the voices of the participants are not directly heard (Cresswell, 2007). In quantitative research alone the researcher seldom discusses his or her personal interpretation and bias. Thus incorporating qualitative research eliminates this weakness. The goal of quantitative methods is to determine whether the predictive generalizations of a theory hold true. In terms of this study the questionnaire has questions which provide numerical data that enabled the researcher to analyse and make comparisons and identify trends in relation to other previous studies and between the two schools and their contextual situations.

Therefore, this study is essentially a qualitative study as the learners were asked to provide information about their knowledge and understanding of biotechnology by responding to the questions given. The interpretations of their responses provide evidence about learners' knowledge of biotechnology in different contexts.

3.3 RESEARCH DESIGN

This section describes and explains the design of the study in terms of data collection and analysis. The development and the implementation of the instrument used in this study will also be explained.

3.3.1 Research instrument

The instrument I used to collect data in this research study was a questionnaire. Many of the studies based on knowledge and attitudes towards biotechnology have used questionnaires to collect data (Kidman, 2009; Chen & Raffan, 1999; Lock, 2007; Sebitosi, 2007). Although questionnaires may have some pitfalls such as the difficulty to capture a rich source of in-depth information or the fact that it may be administered and not returned, it does have many advantages. The benefit of using a questionnaire in my research was that learners had not yet been formally taught about biotechnology and therefore could have been uncomfortable expressing their views if they had to disclose their knowledge in a test as a test would be assessing the knowledge of biotechnology. Questionnaires are less rigid and the learner is anonymous and has the freedom to express their ideas, increasing the chances of an honest response from them. I decided to use a questionnaire as it has a standardised format and every participant is answering the same questions unlike in interviews which sometimes require elaboration to elicit the desired response (Oppenheim, 1966). Questionnaires can reach a large number of participants in a short space of time and are easy to code, analyse, and interpret and are relatively economical as well (Oppenheim, 1966).

The researcher designed the questionnaire with the assistance of her supervisors, and another lecturer in the field of biotechnology education. The questionnaire (see Appendix 1) is based on various literature resources as well as the current grade 9 South African Natural Sciences curriculum. Questions 1, 2.1, 3 and 4 attempted to answer research question 1 i.e. what existing knowledge do grade 9 Natural Sciences learners have about biotechnology? The reason for this research question was to identify and establish the knowledge that grade 9 learners have about biotechnology. Question 5 attempted to address research question 2 in order to determine the attitudes about biotechnology, which exist among grade 9 learners.

3.3.2 Development of the research instrument

When the questionnaire on biotechnology was being developed various literature resources were used (Lock 2007; Kidman, 2009; Dawson & Schibeci, 2003; Dawson & Soames, 2006). Misconceptions related to the understanding of biotechnology were also highlighted in several studies (Kidman, 2009; Chen & Raffan, 1999; Lock, 2007; Sebitosi, 2007). Taking these misconceptions into account guided me in the development of this research questionnaire as it prevented me from repeating the same mistakes by helping to use the appropriate language and also contextualising the questions. For example question 4.1 has questions related to farming and traditional biotechnology. The majority of the learners at both schools are second language learners and often learners experience difficulty in the interpretation of the questions.

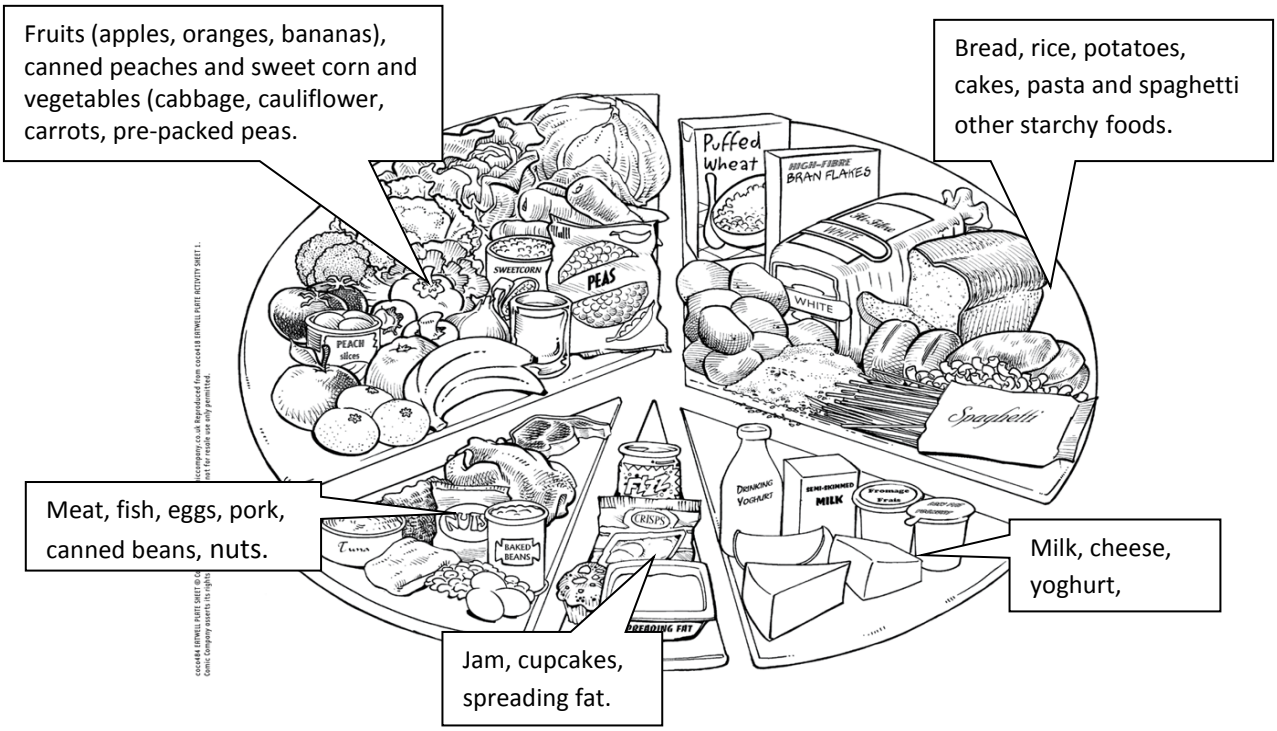
Two questions included in the questionnaire i.e. questions 2 and 4 (Appendix 1) were adapted from previous studies conducted by Dawson & Schibeci (2003) and Dawson & Soames (2006). Question 1 was taken from a biotechnology course module that was prepared by Nyamupangedengu, one of my supervisors and Question 5 was adapted from Dawson & Soames (2006). Question 3 and 4.2 and 4.3 were developed by me with of assistance of my peers and supervisors. I decided to use five questions in the questionnaire. These five questions address both aspects of the research which are knowledge of and attitudes towards biotechnology. For this research study, since there was no other method of acquiring information from the learners, a reasoning aspect was included for questions 4 and 5 to provide the learner with an opportunity to express their views in terms of their attitudes towards biotechnology. This enabled me to gain further insight into their understanding and prior knowledge as well as their attitudes about biotechnology.

Knowledge-based Questions

Question 1 below was intended to find out if the learners could identify foods produced with the aid of biotechnology. For each identified food the learner had to provide a reason for the choice and this information helped me to interpret the learners' train of thought.

QUESTION: 1

The diagram below is a plate showing a variety of foods. Identify any foods produced with the aid of biotechnology. In each case suggest a reason for including it as a product of biotechnology. Write your answer in the table below.



Adapted by Eunice Nyamupangedengu from:
http://www.educationscotland.gov.uk/resources/c/cpdsupportframeworktodeveloppracticalfoodskills/nutrition.asp

Type of food	Reason for including it as a biotechnology product

Question 2.1 says:

2.1 Have you heard of the terms listed below? Indicate your answer by placing a tick (√) in the appropriate space provided.

TERMS		
1. Cloning	☐ YES	☐ NO
2. Genetically modified organisms	☐ YES	☐ NO
3. Genes	☐ YES	☐ NO
4. Stem cell Research	☐ YES	☐ NO
5. DNA	☐ YES	☐ NO

This question was intended to find out if the learners have heard about the above mentioned terms as this is an indication that either they are aware of them or may even have some information about the terms. This question then leads to question 2.2 which states:

2.2 Tick (√) in the spaces provided in the table below to let me know where or how you may have heard of the above terms. You may choose more than one option.

Did you hear these terms from:	Cloning	Genetically modified organisms	Genes	DNA	Stem cell Research
Teachers					
Friends					
Parents, guardians					
Grand parents					
Internet access					
Magazines you have read					
Media presentations on TV or radio					
Other					

Question 2.2 required information on where learners get their knowledge about biotechnology from. Learners often acquire knowledge from various sources and try to make associations with their existing knowledge and sometimes these associations are reflected in their explanations.

Question 3 states:

3. Look at the diagram below that shows a cow and its calf.

3.1.1 Do you think the calf has been cloned? Tick (√) the block of your choice.

YES ☐ **NO** ☐ **I DON'T KNOW** ☐

3.1.2 If your answer is YES or NO, give a reason for your choice.

The purpose of question three was to find out if learners knew what the term cloning meant and whether they could associate the process with biotechnology in their reasoning. However, a negative response to Q 2.1 may be an indication that the learner will be unable to explain cloning either as a concept or in terms of a biotechnology process. Question 3.1.2 was intentional and the results show that answering "yes" or "no" was not enough as they had to provide an explanation.

Question 4.1 says:

The statements below about biotechnology and its uses are either True or False.

Read the statements and put a tick (√) in the space provided and give a reason for your choice.

The statements are listed below:

Statement	True	False	Reason
1. Ordinary tomatoes do not have genes while genetically modified tomatoes have genes.			
2. Biotechnology is a process that interferes with nature			
3. Making traditional beer and bread using yeast cells is a biotechnology process.			
4. Scientists have changed the genes of certain plants for the benefit to farmers.			
5. If a person eats a genetically modified apple, their own genes can be changed.			

The above statements are related to genes and genetic modification of both plants and animals. By genetically modifying organisms, genes have to be manipulated in order to get the desired effect. The rationale for each statement in question 4.1 was to investigate what knowledge the learners had about genes and genetic modification as a biotechnology process. It was also intended to determine whether the learner understood or had knowledge of how micro-organisms can be used for the benefit of our daily lives. The reasoning aspect was included in order for the learner to express their views about the statements and therefore provide insight to the researcher about their knowledge towards biotechnology.

Question 4.2 states what is Biotechnology? (How would you explain biotechnology to a friend?). The rationale for this question was to determine if the learner had knowledge of biotechnology and if that knowledge can be communicated. The question was also intended to obtain any misconceptions about biotechnology.

Question 4.3 states Describe THREE ways in which biotechnology can help people live better lives in a healthier world. The idea behind this question was to establish learners'

understanding of biotechnology and to ascertain what views they had about biotechnology in terms of improving the quality of life.

Attitude-Based Question

Question five was used to elicit learners' attitudes to different types of biotechnology and the statements were adapted from Dawson & Schibeci (2003) and Dawson & Soames (2006) and states:

The statements are about biotechnology processes. For each statement, place a tick (√) for unacceptable or acceptable in the space provided and give a reason for your choice.

STATEMENT	ACCEPTABLE	UNACCEPTABLE	REASON
1. Using genetically engineered micro-organisms to enable more efficient breaking down of human sewage.			
2. Changing the genes of plants so that they will grow better in salty soils.			
3. Altering the genes in an embryo* to treat a genetic disease.			
4. Adding genes to plants to increase their nutritional value.			
5. Altering the genes in fruit to improve their taste.			
6. Inserting genes from micro-organisms into crops to provide pesticide resistance.			
7. Inserting genes from plants into animals.			
8. Adding genes to yeast that is then used to make better tasting bread.			

The purpose of the above question was to investigate if the learners find applications of biotechnology in our daily lives, acceptable or unacceptable. The learner's explanation in the reason column was intended for the learner to express his or her attitudes towards biotechnology. With an increasing population, disposal of sewage waste has become a problem. Statements 1 and 8 were intended to establish the stance the learner would take with respect to the use of micro-organisms to treat sewage waste and enhancing the taste of food. Statements 2, 4, 5 and 6 were about the manipulation of genes of plants to grow in salty soils, to increase their nutritional value or improve their taste and make them pest resistant. The rationale for these statements was to determine the attitudes of the learner with respect to altering organisms for the benefit of mankind. The rationale for statement 3 was to find out if learners understood the influence of genes in the medical field and whether they accepted or did not accept the use of the embryo to treat genetic diseases. Question 7 was included to find out if learners knew about inserting of genes across the species barrier; however the shortfall of this question is that an example was not given.

3.3.3 Participants and sampling

Two government schools in the Gauteng province were chosen to participate in this study. The first of which is school A, an ex-model C school in the suburb of Midrand and the second government school, school B is in a township area in Tembisa. A sub-urban area is a residential area on the outskirts of the city. School A, a co-educational school provides education to learners from affluent backgrounds and it is well resourced in terms of facilities that are accessible to the learners e.g. computer laboratory with internet access. In South Africa a township is categorised as a segregated residential area on the outside of a city or town. School B is not as well resourced as school A and provides education to learners from relatively low to medium income households. The learners in grade 9 in school A were between the ages of 14 to 17 years old and represented a diverse cultural community. Grade 9 learners in school B, on the other hand were represented by Black African learners only between the ages of 14 to 16 years. School A, a co-ed multilingual and multiracial school (grade 8 to 12), comprised of 210 grade 9 learners while school B, also a co-ed school comprised of 150 grade 9 learners. The reason for the variation in context was to derive a comparison and to identify how the environment, to which these individuals were exposed, influenced the knowledge they had about and their attitudes towards biotechnology. All grade

9 learners in both schools answered the questionnaire to avoid learners feeling discriminated against.

Once the questionnaires were handed back to me I separated them according to completed, almost complete and incomplete questionnaires. I then selected from the questionnaire with completed and almost completed responses. Twenty five questionnaires with completed responses were chosen randomly from each school. Some learners were reluctant to participate in the research therefore only those learners from the selection that had consented to participate were used in the study; hence the selection of the sample was convenient. The two schools are in close proximity to where the researcher lives. This made access to the schools easier and also decreased expenses for travelling. It was also convenient as the researcher was able to obtain the responses immediately as well instead of waiting for post. It is also important to note the sample is a very small representation of the larger target population of grade 9 learners' and as a result has potential for bias since learners' interpret and understand things differently (Fraenkel & Wallen, 1990). The results of this study cannot be generalised beyond the study sample.

3.3.4 Improving the rigour of my research

In order to improve the quality of this research there was a need to look into issues concerning trustworthiness. For quantitative researchers such as Joppe (2000) and Kirk & Miller (1986), consistency, repeatability of the results or observations over time and the similarity of measurements are important in determining the degree of reliability of the research. However, in qualitative research, trustworthiness in research indicates that the research should be dependable, credible and confirmable. These concepts according to Scaife (2004) are extensions of the concepts validity and reliability.

Validity refers to whether the research truly measures that which it is intended to measure or how truthful the research results are, in other words does this study enable the researcher to achieve his or her objectives (Golfshani, 2003). Secondly validity in terms of quantitative research takes into account the accuracy of the measurement and whether the research has measured that which it was intended for. In this research study, the researcher used two approaches i.e. face validation and pilot-testing, to improve the quality, standard and trustworthiness of the instrument. These are described below.

Validation of the questionnaire

The validity of the questionnaire was checked through face validation and content validation. Face validation involved the use of an expert in a specific field of study to check if the instrument measures that which it is intended to measure (Badgett & Christmann, 2009). Face validation is also subjective judgement of an instrument that may be used for the purpose of research (Drost, 2011). For instance, in terms of this study, the appropriateness of the instrument was taken into account to ensure that learners would be able to understand what is asked of them and provide the appropriate response. Content validation refers to a theoretical concept which focuses on the extent to which the instrument of measurement shows evidence of fair and comprehensive coverage of the topic that it purports to cover (Oluwatayo, 2012). The questionnaire was given to an experienced senior Life Sciences colleague who teaches Life Sciences in the FET phase and Natural Sciences in the GET phase. The researcher's colleague was tasked to do both content and face validation of the questionnaire. Content validation is the extent to which the instrument (questionnaire) covers the content (biotechnology) that is being researched and face validation is simply whether the instrument (questionnaire) measures what it claims to measure i.e. does the questionnaire measure knowledge of and attitudes towards biotechnology? The questionnaire was also given to a Senior lecturer at the Wits School of Education and the lecturer was seen as an expert as he had conducted research in biotechnology previously. Both these academics were requested to examine the questionnaire by checking the relevance of the questionnaire in terms of the topic under study. Issues pertaining to the appropriate use of language as well as the layout of the questionnaire were raised. The initial questionnaire consisted of scenario type questions and it was brought to my attention that learners might not have the appropriate vocabulary or specific knowledge to explain the concept of biotechnology and its use in society. The experts in terms of biotechnology knowledge also indicated that the level of language might be too high as a result learners more especially second language learners would experience difficulty in answering appropriately. Therefore, I reworded the questions to target the appropriate response. It was also suggested that short simple questions be used in order to prevent the learner from becoming anxious and irritable when answering. Face validation proved to be a very important aspect as it allowed me to develop the questionnaire such that the learner could understand what was being asked and therefore measure the knowledge of and attitude towards biotechnology.

Pilot study

A pilot study is a "pre-study" of the researcher's complete study. The importance of a pilot study is to identify the relevance and appropriateness of the instrument being used and to identify potential problems that may affect the quality and validity of the results (Blessing & Chakrabathi, 2009). A pilot study permits a thorough check of the planned statistical and analytical procedures giving the researcher an opportunity to evaluate the usefulness of the data. After the questionnaire had been (face and content) validated the researcher conducted a pilot study for further validation of the research instrument. The questionnaire was piloted with 6 grade 8 learners for the following reasons:

- To determine the issues of time frame required for the learners to completely answer the questions.
- To determine if the appropriate level of language was used and whether the learners have interpreted the questions correctly based on the responses they have provided.
- To greatly reduce the number of unanticipated problems as piloting the research instrument gives the researcher the opportunity to redesign it and overcome the barriers and difficulties that may have been experienced. This ensures that the study is effective and efficient (Blessing & Chakrabathi, 2009).

The pilot study was conducted with grade 8 learners at school A where the study was to be conducted. The reason for conducting the pilot study with grade 8 learners instead of grade 9 learners was to prevent a situation of collusion among grade 9 learners as they were participants in the study. This was also done to avoid bias as piloting the questionnaire with grade 9 learners could lead to discussion among the group and therefore the results would be compromised and would not be trustworthy or a true reflection of the knowledge and ideas that the learners have. The pilot study could have also been conducted with grade 9 learners from a non participating school. However, there were no schools within close proximity.

The analysis of the responses from learners that participated in the pilot study showed that the appropriate language was used as the learners understood the questions that were posed. The time allocated for the pilot study also indicated that the learners may need an additional 10 minutes to complete the answers. Learners of the pilot study made use of the appropriate

vocabulary to answer the questions and that was indeed an indication that the learners have some knowledge of biotechnology. An example of a response from one of the grade 8 learners for question 1 was "fruits are genetically modified to grow throughout the year." The learner was also able to explain biotechnology as "the way, in which scientists alter organisms, preserve food, recreate organisms and develop ways to change natural processes in order to help humans." After having considered the results there was no need to alter the questionnaire in any way so the researcher carried out the investigation accordingly.

Reliability

Joppe (2000, p.1) defines reliability as "the extent to which results are consistent over time and an accurate representation of the total population under study". The questionnaire was given to both schools simultaneously with the assistance of fellow colleagues. A discussion about the questionnaire and the administration procedure was held prior to conducting the investigation in order to maintain consistency between the two schools. My colleagues were given clear written instructions so that there was no deviation in the explanations to the learners.

3.4 ADMINISTRATION OF THE QUESTIONNAIRE

On completion of the validation and pilot study the relevant alterations were effected. The researcher is an educator at school A. A colleague from school B arranged and assisted the researcher in administering the questionnaire at school B. A and B are used as pseudonyms for the schools to avoid revealing the names of the schools and they will be represented in this manner throughout the report. The colleague had made arrangements to include the questionnaire as part of their school based assessment plan. Questionnaires and consent forms (Appendix 4) were given to the colleague in school B and the entire procedure was explained to him and the learners prior to answering the questionnaire. In both participating schools, the learners were seated in separate venues in their register classes and each teacher was given clear written instructions. Each question was explained to the learners and they were given 10 minutes to read through the questionnaire. The learners were also given the opportunity to ask questions and clarify any misunderstanding. The learners were made fully aware that they were not writing a test. Learners were informed that they will not be forced to participate in the research and that only those who gave consent will be included. The learners were given

an hour and twenty minutes to complete the questionnaire. All questionnaires were collected irrespective of whether they were filled in or not.

3.5 DATA ANALYSIS

Data analysis in qualitative research means making sense of collected data (Hatch, 2002). It involves systematically analysing gathered data in order to understand and interpret the meaning of the answers given. The first stage of my data analysis involved processing the data. Processing of the data included coding the questionnaires. The questionnaires were initially coded according to the school from which they came. Each respondent was given a label such as L2 B. L2 stands for learner 2 and B represents the school. All respective data from the responses given were captured using an excel spreadsheet. For questions 1, 4 and 5 codes were used to analyse the response of the learners'. The following codes listed below emerged in order to facilitate interpretation of the responses of the learner.

Descriptive codes used for analysis of learner responses

- **Clear knowledge** or correct knowledge – learners' response is correct.
- **Partial knowledge** – learners' responses show evidence of some correct understanding of the biotechnology concept but the understanding is not very clear.
- **Poor knowledge with misconception** – learners' response show clearly that the learner lacks knowledge and whatever idea does exist is misunderstood or misinterpreted.

The food plate in question 1 is divided into five food groups and they are categorised clockwise as carbohydrates, dairy, fats, proteins and fruit and vegetables. Each category will be discussed separately in chapter 4, with examples of learner responses given as evidence. For question 1 all data as expressed by the learner, was captured as is, key words or phrases used by the learners were colour coded so that the repetition of the information could be easily seen, for example, the definition that was used to code learners' responses is:

Biotechnology is the practical use of biological systems to produce goods or products and it includes transformation of materials by micro-organisms (e.g. Fermentation), methods of

propagation such as plant cloning or grafting, may involve genetic alteration (modification) through selective or artificial breeding.

Below is an example of a coded response from learner 9. The green colour represents a response with a misconception and the yellow colour represents correct information according to the definition above.

L9 (B)	
Food type 1	Bread because it includes genes which comes from yeast.
Food type 2	Cheese - because it is made by bacteria.
Food type 3	Cakes because it also has yeast on it.
Food type 4	Canned beans because they added chemicals to make it last long.
Food type 5	Apples because it has genes which gives it the taste. Cabbage because it had no gene it would not have the green colour.

The information for question 2 was captured in a table from which relevant graphs were constructed to show whether the learners have indeed heard the respective terms previously and to identify what the possible sources of their information were. The table below is an example of how the information was captured. The table shows learners who indicated that their source of information for the concepts shown was the internet.

internet access				
Cloning	GMO	Genes	DNA	Stem Cell Research
L1 (A)		L1 (A)		
				L2 (A)
L3 (A)			L3 (A)	

In question 3 the definition of cloning was used to determine whether the learner did have knowledge and understanding of the term. According to Devolder, (2013) cloning is the creation of a genetic or exact copy of a sequence of DNA or of the entire genome of an organism.

For example,

> L 1A the two cows are not identical so it cannot be a cloned cow. One is bigger (mother) and the other is smaller and the spots are not the same so it cannot be cloned.

According to L1A, the cows are not identical and therefore do not have an exact copy of DNA therefore it cannot be cloned.

For question 4 and 5 an explanation of the learner's choice of phrases was required and the researcher had to interrogate the underlying meaning of the data by categorising the texts or phrases. The statements from question 4 and 5 were used to develop the following categories:

- Knowledge and understanding of Biotechnology
- Misconceptions related to Biotechnology
- Attitudes towards Biotechnology
- Sources of information on Biotechnology

Key words such as use of chemicals or the use of bacteria or the alteration of genes were used to identify the learners' response and hence interpret the phrases accordingly. Below is an example of a learner's response that falls under the category knowledge and understanding:

> L 7A Ordinary tomatoes have genes while genetically modified tomatoes do not have genes.

Clearly this response shows there is some knowledge of genes and genetic modification but there is also the element of misconception and lack of knowledge.

3.6 ETHICS

"Ethics relates to the application of moral principles to prevent harming or wronging others, to promote the good, to be respectful and fair" (Sieber, 1993, p. 14 cited in Opie, 2004). The researcher has considered the ethical implications for this study and in terms of the University of Witwatersrand's Human Research Ethics Committee. I have ethical clearance (Appendix 5) and I have also followed the rules and requirements that have been stipulated. School

Principals of the participating schools were briefed about the intentions of this study and letters of consent were signed granting permission to go ahead with the research (Appendix 4.4). Information sheets (Appendix 4.1 and 4.3) ensuring confidentiality, anonymity and disclosing all aspects of my research and consent forms were given to the learners and their parents requesting permission for participation in the research. Thank you letters have also been sent to the participating institutions for allowing the research to be conducted there.

3.7 CONCLUDING REMARKS

In this chapter the design of the research was clearly described, explaining issues of validity and reliability. The instrument used for the research was also described in detail by including the questions within the text, including the sample and the sampling technique. A description of the procedure for collecting and analysing data was presented and the emergent coding system used during the analysis was explained. In the next chapter the analysis of data and the results are presented.

CHAPTER FOUR

Results and Discussion

4.1 INTRODUCTION

This study focused on exploring the knowledge and attitudes of grade 9 learners towards biotechnology. In this chapter the results of the research are presented and discussed. The results are presented in themes and the findings of the study are discussed in terms of the research questions stated below:

1. What existing knowledge do grade 9 Natural Sciences learners have about biotechnology?

2. What are the attitudes of grade 9 Natural Sciences learners towards biotechnology?

The success of introducing biotechnology to learners lies in the importance of tapping into their pre-conceived or inherent understanding and attitudes. Biotechnology has been studied globally in Australia, New Zealand, UK and Taiwan and Turkey (Dawson & Schibeci, 2003; Chen & Raffan, 1999; Kidman, 2009 and Lock, 2007). Clearly these studies report that learners enter the classroom with their own world view about biotechnology. The world view of the learners as reflected in my study will be presented using the four categories below, i.e.

- Knowledge and understanding of Biotechnology
- Misconceptions related to Biotechnology
- Attitudes towards Biotechnology
- Resources of information on Biotechnology

I derived these categories from my questions and I will present my findings using these categories as headings. The research questions have been used to structure and outline the presentation of results in this chapter and the information or data is organised and arranged in tables or graphs making it easily accessible. Symbols such as L25B are given to the learners to identify them and their schools respectively. In the case of this example, B is the school and 25 is the 25^{th} learner from school B.

4.2 KNOWLEDGE AND UNDERSTANDING OF BIOTECHNOLOGY.

One of the objectives of this study was to find out what knowledge grade 9 learners have about biotechnology since the first formal detailed encounter of the concept is in grade 10, if the learner chooses Life Sciences as part of their career path. In this study question 1, 2.1, 3 and 4 of the questionnaire (Appendix 1) were knowledge-based questions.

4.2.1 Learners knowledge of foods produced through biotechnology

The intention of question 1 was twofold:

- firstly to identify if the learner had prior or existing knowledge of biotechnology and
- secondly to find out whether the learner was able to identify any biotechnology processes that may have been applied to the foods shown on the food plate.

In order to interpret and analyse the information presented by the learners, I had to find a definition of the concept Biotechnology, making certain that it incorporates the necessary practices and applications. As stated in chapter 2, Biotechnology has been used since the dawn of civilisation. According to a document prepared by the Pennsylvanian Department of Education (2002), very simply biotechnology can be described in terms of "Bio" representing a science of all living things and "Technology" representing the tools and techniques used to apply our knowledge so that living organisms respond as we want them to. However, the concept biotechnology has many definitions according to its context or purpose. The earlier New Zealand technology curriculum of 1995 claim that biotechnology can be described as;

> The use of living organisms, systems, or parts of organisms to manipulate natural processes in order to develop products, systems or environments to benefit the people (Herren, 2012).

Biocatalysts on the other hand claim that;

> Biotechnology is a branch of science in which living organisms (micro-organisms such as bacteria, yeast) are used to produce food, drink, and medicines or for other benefits to humans, or other animal species" (Biocatalysts LTD, 2014)

Therefore, the interpretation of what biotechnology is can be very broad, e.g. a wooden chair is an example of biotechnology since it originated from a living organism. It can also be a relatively broader interpretation covering both ancient and modern biotechnologies including the following:-

- products – e.g. food, pharmaceuticals
- systems – e.g. waste management, compost
- environments – e.g. water purification (hydroponics, bio control)
- genetical engineering – e.g. stem cell therapy, genetic cloning, genetically modified crops.
- selective breeding – e.g. enhancing traits of plants and animals through selection and cross breeding, (biotechlearn.org.nz).

Key words from the definition were used to analyse the response from the learners. The learners were asked to identify any foods produced with the aid of biotechnology and in each case the learner was asked to provide a reason for including it as a biotechnology product. As described in chapter 3, the products on the food plate in question 1 (Appendix 1) is divided into 5 food groups and they are categorised clockwise, i.e. carbohydrates, dairy, fats or lipids, proteins and fruit and vegetables. Each category will be discussed independently with examples of learner responses. As described in chapter 3, the learners' responses have also been categorised as having clear knowledge, partial knowledge, poor knowledge with misconceptions and no responses. For all five food groups the results will be displayed in a table.

Since this study is a qualitative study interpretation of the responses is subjective. My experience during the analysis and interpretation of the responses proved that it is a difficult task to interpret and try and understand the thought of others. This created many challenges but also provided me with an opportunity to research more information in order to gain a better understanding.

The table below shows how many learners were able to provide a response concerning biotechnology products, with an elaboration of their answers for all five food groups.

Table 4.1 Learners knowledge of foods produced through biotecnology processes

	Types of foods	Carbohydrates		Dairy		Lipids or Fats		Proteins		Fruit & Vegetables		TOTAL	
	Schools	A	B	A	B	A	B	A	B	A	B	A	B
Learner Response	Clear Knowledge	9 36%	7 28%	5 20%	2 8%	3 12%	9 36%	3 12%	4 16%	4 16%	1 4%	24 96%	23 92%
	Partial Knowledge	9 36%	5 20%	5 20%	5 20%	5 20%	7 28%	4 16%	5 20%	2 8%	3 12%	25 100%	25 100%
	Poor Knowledge with misconceptions	0 0	8 32%	4 16%	10 40%	3 12%	2 8%	4 16%	2 8%	0 0	2 8%	11 44%	24 96%
	No Response	7 28%	5 20%	6 24%	8 32%	4 16%	6 24%	5 20%	4 16%	3 12%	2 10%	25 100%	25 100%

Key: A is school A (n=25) and B is school B (n=25); T = Total number of responses from learners in both schools (N=50)

Carbohydrates

Some learners from school A (36%) show clear knowledge of carbohydrates e.g. bread being a product of biotechnology as yeast is used in the baking of bread. Fewer learners in school B (28%) shows knowledge about biotechnology. Below are examples of learners from both schools showing their responses that show clear knowledge of carbohydrates being processed using biotechnology.

L4 B	*Bread - yeast is used in making bread Spaghetti is made from wheat.*	***Clear Knowledge***
L6 B	*Bread because yeast has been used.*	***Clear knowledge***
L25 B	*Baking bread is a process of biotechnology.*	***Clear knowledge***
L14 A	*Bread - Yeast is added to the bread to rise*	***Clear knowledge***
L4 A	*Bread has to be added yeast*	***Clear knowledge***
L20 A	*Puffed wheat – genetically modified to be puffy*	***Clear knowledge***

The above responses show that some learners in both schools (A-36% and B-28%) indeed have some background knowledge of biotechnology. One learner (L25 B) identified baking

bread as a biotechnological process. Learners indicated that yeast, a micro-organism was used in the process of making the bread. Certain corn in cereals has been modified to create puffed wheat and the statement indicated by L20 A shows that he or she is aware of the applications of biotechnology.

South Africa is the current leading exporter of genetically modified organism (GMO) in Africa with a local production of 80% of GM maize, 90% of GM soya bean and 100 % of GM cottonseed (Viljoen, Dajee & Botha, 2006). Despite the fact that genetically modified organisms have been grown commercially in SA since 1997, these authors contend that there is very little consumer awareness. While there are learners that have the ability to identify biotechnology processes, there are others that have identified a process and within their explanation of the process a misconception still exists. These misconceptions are highlighted in the following statements:

L5 B	*Bread has yeast genes to produce it.*	***Misconception***
L9 B	*Bread because it includes genes which comes from yeast*	***Misconception***
L19 B	*Bread - genetically modifications = fermentation.*	***Misconception***
L18 B	*Bread and potatoes - genetically modified = fermentation. Spaghetti & pasta - they put medication in it so that they can grow.*	***Misconception***

Thirty two percent of the learners in school B have misconceptions about yeast and genes, and none in school A. The learners know what yeast is used for but they do not know what it is. The above statements are considered to be misconceptions as genes do not in any way influence the baking of bread and fermentation is not a process that occurs as a result of modifying genes. Yeast is the anchoring concept here; therefore for the educator it would be beneficial to use this as a starting point. The teacher could build upon the existing knowledge by starting with yeast being a micro-organism and then describe the fermentation process relating it to biotechnology.

Learners L5 B and L9 B are aware that yeast is used to make bread; however, the learners have a misconception that it is the genes present in the yeast that are making the changes in the bread. Learners L19 B and L18 B both speak of genetic modification with implication that bread is genetically modified through a process of fermentation. Both these learners

come from school B which is situated in a township area as described in chapter 3. The learners could have described bread making as genetic modification through the process of fermentation as they are familiar with the use of yeast when traditional beer and bread is made. The likely possibility is that these learners are making associations with their real life experiences as they are aware that yeast is for the process of fermentation. If this is the case then Ausubel's theory of subsumption holds true as these learners have developed anchoring concepts through interaction in their environment.

Dairy

The dairy industry makes use of biotechnological techniques and applications to produce a wide range of dairy products. In South Africa milk production contributes about 0.5% of the world's production of milk (Department of Agriculture, 2013/2014). For the majority of the Indian population in India, particularly those belonging to the vegetarian section, milk and its products constitute the major affordable source of animal proteins for growth and health. Research shows that genetically engineered milk is possible as scientists are able to produce infant milk by adding human lactoferrin or lysozyme to bovine milk to produce functional foods (Batish & Grover, 2003). Below are a few responses of learners relating to dairy products and their manufacture using biotechnology processes.

L25 B *Cheese and yoghurt is made using good bacteria.* ***Clear knowledge***

L14 A Yoghurt includes preservatives. Cheese making is a biotechnology process because ingredients such as bacteria (blue cheese) are sometimes added. ***Clear knowledge***

L4 B Bacteria is used to make cheese ***Clear knowledge***

L13 A Milk because the genes of the cow can be altered so that the milk tastes better. ***Clear knowledge***

From the above responses it shows that some learners (28% A and B combined – table 4.1) do indeed have some understanding of biotechnology, for example, cheese and yoghurt are made using good bacteria. A micro-organism is used and in this case live cultures are found in yoghurts thus giving them that tangy taste. Taking into account the learners' responses one can conclude that they are aware of the biotechnology products they may encounter on a

daily basis. Learner L13A shows that he /she is aware that through genetic manipulation it's possible to produce better tasting milk. There are three possible anchoring concepts here i.e. knowledge that bacteria which are living organisms are used in cheese and yoghurt production and knowledge of genes and that the genes can be altered. The educator can use these anchoring concepts from the above responses to build further on the learners' knowledge facilitating assimilation into their existing knowledge.

Batish & Grover (2003) also claim that nutrients of the GM milk are as good as human milk and contain the necessary substances to build and develop the immune system as well. Only one learner had given milk as an example of a biotechnology product and the rest of the learners provided cheese and yoghurt as examples.

Fats or Lipids

Typical ideas of learners about lipids and their biotechnological use are listed below.

L17 A Spreading fat extracted from animal & processed so that it is suitable.
Partial Knowledge

L25 A Jam, cupcakes, spreading fat - Their taste is enhanced by using biotechnology.
Partial knowledge

L23 A Fats & oils - keeps the body warm. ***Partial knowledge with misconception***

L14 A Jam is preserved fruit. Ingredients are added to keep the jam fresh.
Clear knowledge

The responses of the learners were classified as shown above in order to analyse appropriately. The making of jam has been practiced for centuries. Homemade jams are made by boiling fruit and then adding sugar as a preserve. Presently jams are produced commercially and on a large scale. Jams produced on a large scale require preservatives to keep them longer on the shelves as indicated by learners L14A and L25A above. Apart from identifying the biotechnology processes, learner L23A has indicated that we need fats to keep the body warm and this suggests that the learner is knowledgeable about the functions of fats and oils, however is unable to explain the use of fats in terms of biotechnology. This could possibly be a statement as a result of a misconception as well. As indicated in Table 4.1, 44% of the learners in school A and 28% of school B have partial knowledge relating to fats or lipids.

Proteins

Animal biotechnology has also been practiced for thousands of years with cattle farmers breeding cattle to produce the desired traits that they require. Current practices include examples of transgenic[1]animals. Transgenic animals are used to clone large quantities of the gene responsible for the cattle growth hormone. The hormone is removed from the bacterium purified and injected into dairy cows. This hormone stimulates the production of milk increasing the cow's milk production by 10 to 15 percent.

L25 A	*Meat, fish and eggs - chemicals included cause the animal to become bigger.*	***Clear knowledge***
L16 A	*Canned vegetables - has preservatives & are unhealthy*	***Partial knowledge***
L6 B	*Fish & eggs can be artificially made to increase proteins in the human body & can be modified to resist pests.*	***Clear knowledge***
L1 B	*Meat has proteins and keeps our body strong*	***Poor knowledge – no biotechnology included***
L22 A	*Poultry - source of iron.*	***Poor knowledge – no biotechnology included***

The response of two (L25A and L6B) learners above shows some knowledge about manipulating animals for the desired benefit of mankind. These learners have an idea that chemicals (maybe growth hormones) injected into the animal could make them bigger, hence this could be an anchoring concept that the teacher could use to extend the learners knowledge. Learners from both schools seem to have a relatively fair understanding of proteins and related biotechnology. In table 4.1 40% of the learners in school B and 44% of learners in school A show partial knowledge of proteins in terms of their functions but are unable to relate the biotechnology practice associated with it e.g. L1 B. Learner L22A in school A indicates that poultry is a source of iron rather than protein thereby indicating confusion as well as misinformation. However, he or she could have been referring to eggs in which case he/she would be correct in saying that eggs are a source of iron. Although this information might be correct in terms of knowledge, there is no indication of biotechnology application associated with it and hence does not answer the question.

[1] A transgenic organism is simply an organism that has DNA from another species inserted into its genome (Crawford, 2011)

Fruits and vegetables

Learners were able to give a variety of responses with respect to fruit and vegetables and their biotechnology applications as indicated below.

L7 B	*Fruits contain genes added to them to improve the taste. Vegetables to improve the growth, taste and freshness. Pre - packed peas can be modified to resists pests.* ***Clear knowledge***
L9 B	*Apples because it has genes which gives it the taste. Cabbage because if it had no gene it would not have the green colour.* ***Poor knowledge with misconceptions***
L2 A	*Sweet corn, cauliflower, pre-packed peas - to make it taste better and sweet and I do not like it.* ***Clear knowledge***
L25 A	*Fruits - can be genetically modified Vegetables - can alter the genes for better tasting vegetables.* ***Clear knowledge***

Three learners (L7 B, L2 A, and L25 A) show a clear knowledge of biotechnology in their statements. In two of the statements it is suggested that genes can either be altered or added to modify either fruits or vegetable to improve their taste. However learner L9B is claiming that genes are present in apples and that cabbage also have genes coding for chlorophyll as per the response. This is correct in terms of genes for both the apple and the cabbage; however the learner shows a lack of knowledge of the functions of genes. The learner is unable to link the altering of the genes to improve their taste to applications in biotechnology. Only four (16%) of the learners in school A were able to give clear knowledge of applications related to biotechnology while one (4%) learner in school B was able to. Learners in both schools were able to provide examples of fruit or vegetables that have been genetically altered to improve taste and this is an indication that there is some knowledge of biotechnology.

A review of the results for all food groups in Table 4.1 shows that 96% of the learners from school A and 92% of the learners from school B had a clear knowledge for question 1. Learners from both schools show that they have partial knowledge in terms of biotechnology and the different food groups as reflected in table 4.1. A comparison of both schools shows that learners from school B (96%) hold many more misconceptions as compared to school A (44%). Learners from school B (40%) shows greater misconception as compared to school A (16%). However, for fats and proteins school A show that more learners have misconceptions

as compared to school A, as reflected in table 4.1. This could have resulted due to lack of resources or inadequate understanding of the process of biotechnology or misinformation.

Studies of learners between the ages of 15 to 19 years from the UK, Taiwan and Australia show between 20 -50% have little understanding of biotechnology and its implications (Chen & Raffan, 1999). According to Chen & Raffan (1999), 83% of the total group could give some explanations of what genetic engineering meant. In this study learners were able to give examples of alteration of genes in terms of fruit and vegetables and milk production. In this study, table 4.1 shows that a greater percentage of learners in school A (28%) were unable to give an explanation for carbohydrates being products of a biotechnology process while learners from school B (32%) showed a greater percentage of lack of knowledge for dairy products as a biotechnology product.

4.2.2 Knowledge of Terminology

One area of science and technology that has been increasing very rapidly is the field of biotechnology. Our society has become largely aware of the applications related to biotechnology as the media, newspapers and magazines have covered advancement in related technologies extensively. Seeing as this is the case learners and educators need to be knowledgeable about biotechnology so that they can make informed decisions when the need arises.

The aim of question 2.1 below was to find out if the learner knew about the following terms i.e. cloning, genetically modified organisms (GMO), genes, stem cell research and DNA. Sebitosi (2007) claims that knowledge of these terms is essential if a learner is to understand the applications of biotechnology.

2.1 Have you heard of the terms listed below? Indicate your answer by placing a tick (√) in the appropriate space provided.

TERMS

1. Cloning	☐ **YES**	☐ **NO**
2. Genetically modified organisms	☐ **YES**	☐ **NO**
3. Genes	☐ **YES**	☐ **NO**
4. Stem cell Research	☐ **YES**	☐ **NO**
5. DNA	☐ **YES**	☐ **NO**

Table 4.2 showing the responses for biotechnology terminology (N =25 for A and N=25 for B)

SCHOOL	A	B	A	B	A	B
TERMINOLOGY	Yes	Yes	No	No	No Response	
Cloning	21 (84%)	16 (64%)	4 (16%)	4 (16%)	0 (0%)	5 (20%)
GMO	11 (44%)	21 (84%)	13 (52%)	0 (0%)	1 (4%)	4 (16%)
GENES	25 (100%)	19 (76%)	0 (0%)	6 (24%)	0 (0%)	0 (0%)
STEM CELL RESEARCH	9 (36%)	9 (36%)	15 (60%)	6 (24%)	1 (4%)	10 (40%)
DNA	24 (96%)	20 (80%)	1 (4%)	0 (0%)	0 (0%)	5 (20%)

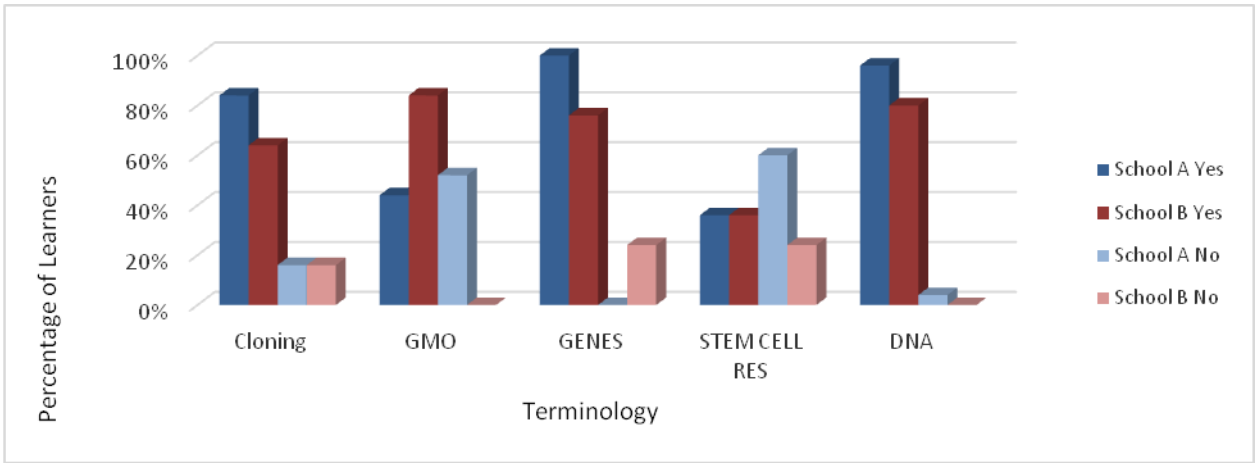


Figure 4.1 Graph showing a comparison of biotechnology terminology between school A (N=25) and B (N=25)

Figure 4.1 shows the number of learners that have indicated that they have heard of or are aware of the terms cloning, GMO, genes, stem cell research and DNA. For both school A and school B, cloning, genetically modified organisms, genes and DNA seem to be terms frequently used. The graph shows that there are more learners who indicated that they have heard of the terms cloning, genetically modified organisms, genes and DNA as compared to stem cell research. According to the graph more learners from school A show an awareness of 3 of the terms i.e. cloning, genes and DNA while school B more learners are aware of GMO as compared to school A. The probable reason for this exposure could be access to different sources of information or the fact that learners from school B might have engaged with more literature pertaining to GMO. The teacher teaching these learners could have also taught the learners extensively about GMO's.

4.2.3 Cloning as an application of Biotechnology

According to Devolder, (2013) cloning is the creation of a genetic or exact copy of a sequence of DNA or of the entire genome of an organism.

Although cloning is regarded as a process that produces an exact copy of an organism, the organism may not be exactly the same due to mutations or chemical changes. This question was intended to find out what knowledge the learners had with respect to cloning. Question 3.1.2 required the learner to express their ideas of cloning to the researcher in order for the researcher to gain insight into their understanding by providing a reason. The results of question 3.1.1 are shown in figure 4.2.

More learners at school B 84% (n=21), indicated that the calf was cloned compared to school A which shows a response of 36% (n=9). For this question the learners were asked to give a reason for the choice made. These are some of the reasons from school A, for answering yes:

L1A The *calf is a clone of its mum. Because now it's old enough and every cow is cloned when they are born .* ***Incorrect***

L20A I think the calf has been cloned because calves are usually not as strong as their parents and this calf appears to have an impeccable amount of strength. The calf has also developed to the size almost as large as the mother cow. ***Incorrect***

L19A When you reproduce the genes of the mother and the father combine so the calf is not an exact copy of the mother. It has some of its father's characteristics and some of the mother's characteristics. ***Clear knowledge***

L17A The two cows are not identical so it cannot be a cloned cow. One is bigger (mother) and the other is smaller and the spots are not the same so it can't cloned. ***Clear knowledge***

L20B IF it was it was going to look alike exactly like the cow and it was going to be genetically be alike with the big one not only physically. ***Clear knowledge***

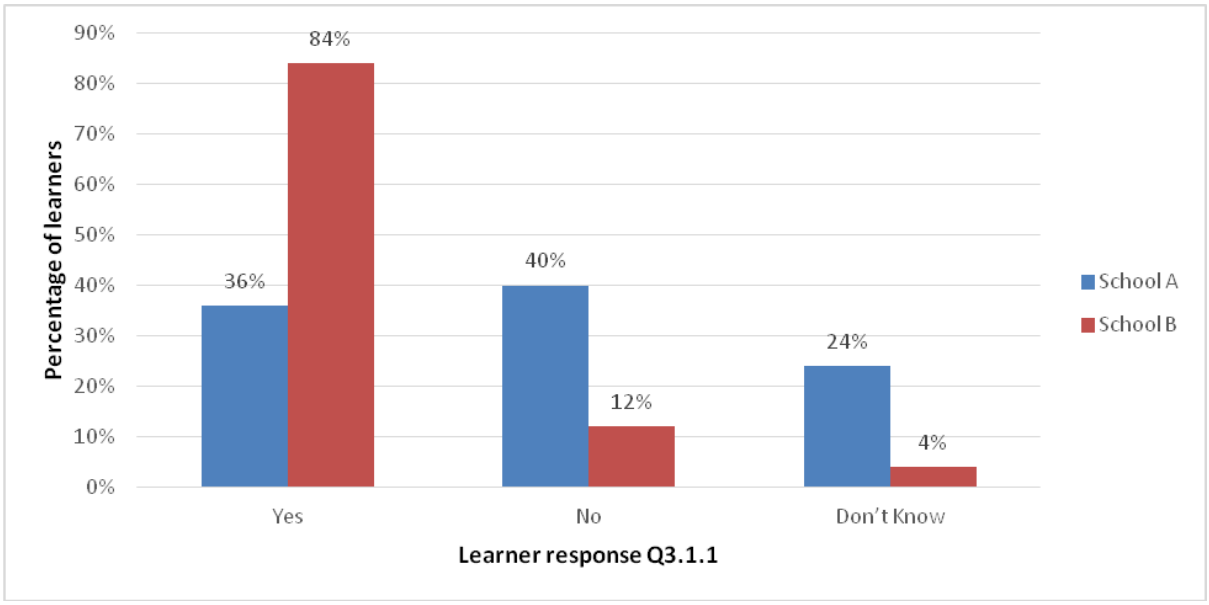


Figure 4.2: Graph showing learner's response about cloning for school A (N=25) and school B (N=25)

The first response is incorrect and shows that the learner assumes that all animals are cloned when they are born. This also shows a misconception that the learner holds. The second response shows the idea that the learner holds is conflicting and confusing. The learner makes assumptions about the strength as a characteristic being passed down and strength is not a

physical characteristic that is outwardly shown. Alternatively the learner could be making the assumption the cloned animal is much stronger; however, this explanation is not valid. The ideas conveyed by the second response indicate a partially correct answer and the learner is taking other aspects into consideration, for example age. These indicate alternative conceptual understanding that the learners have and the educator could use these misconceptions to establish at which point he or she needs to begin in order for the learners to alter their conceptual framework and hence assimilate the relevant information. The learner makes the researcher aware that the calf is still young and cannot resemble the mum completely.

The third response (L19 A) shows that the learner knows about genes and that characteristics are passed down from both parents to the offspring and therefore indicates that it is not a clone. The fourth response that takes size and spots into consideration or thinks they cannot be cloned and according to the definition a cloned organism is an exact copy of a sequence of DNA. The learner could also be suggesting that scientists might have encountered a problem during the process and as a result the difference in the spots. This could probably be as a result of a mutation; however the learner does not have the necessary vocabulary to describe the explanation in terms of a mutation. Therefore it is safe to say different individuals (both scientists and learners) hold varying perspectives of what cloning ought to be described as and this poses a challenge for interpretation. Twenty four percent for school A indicated that they don't know and this could be as a result of the illustration not being concise enough or these learners have clearly not encountered the term or any information about cloning and hence lack of knowledge or understanding, This is an indication that there isn't any anchoring concept from which the teacher can build upon, therefore anchoring concepts would have to be taught first to facilitate understanding.

4.3 MISCONCEPTIONS RELATING TO BIOTECHNOLOGY.

Question four states:

The statements below about biotechnology and its uses are either True or False.

Read the statements and put a tick (√) in the space provided and give a reason for your choice.

The statements are listed below:

Statements:
1. Ordinary tomatoes do not have genes while genetically modified tomatoes have genes.
2. Biotechnology is a process that interferes with nature.
3. Making traditional beer and bread using yeast cells is a biotechnology process.
4. Scientists have changed the genes of certain plants for the benefit to farmers.
5. If a person eats a genetically modified apple, their genes can be changed.

During the analysis of the responses of question 4, I realized that grade 9 learners have various views about biotechnology and its uses in our daily lives. Many of the answers that were given indicated that the learners have several misconceptions. As educators we need to understand that learners do not come to instruction as blank slates but rather with a certain worldview that was created through their physical, mental and social interaction (Smith, diSessa & Rochelle, 1994). Due to these interactions they have developed anchoring concepts that have explanatory power, however sometimes these concepts are inconsistent with scientific concepts presented in instruction. The inconsistency results in misconceptions which impede effective learning (Smith et.al, 1994).

Question 4 was intended to find out about biotechnology and its uses in our daily lives. Five statements were given relating to biotechnology processes and genetic modification or gene manipulation. Learners were expected to state true or false for each statement and then provide an elaboration of their answer. Many misconceptions were evident in the responses from the learners. The table below shows the five statements and the correct answers to it.

Table 4.3: Learners response to biotechnology processes (N=25 School A and N=25 School B)

STATEMENTS	CORRECT ANSWER	CORRECT		INCORRECT		NO RESPONSE	
		A	B	A	B	A	B
1. Ordinary tomatoes do not have genes while genetically modified tomatoes have genes.	False	10 (40%)	19 (76%)	15 (60%)	4 (16%)	0 (0%)	2 (8%)
2. Biotechnology is a process that interferes with nature.	True	19 (76%)	18 (72%)	6 (24%)	5 (20%)	0 (0%)	2 (8%)
3. Making traditional beer and bread using yeast cells is a biotechnology process.	True	21 (84%)	15 (60%)	4 (16%)	8 (32%)	0 (0%)	2 (8%)
4. Scientists have changed the genes of certain plants for the benefit to farmers.	True	20 (80%)	16 (64%)	5 (20%)	7 (28%)	0 (0%)	2 (8%)
5. If a person eats a genetically modified apple, their genes can be changed.	False	14 (56%)	4 (16%)	10 (40%)	4 (16%)	1 (4%)	17 (68%)

Table 4.3 shows the incorrect responses of learners from school A (60%) for statements 1 is relatively high compared to all other responses from statements 2 to 5. The graph in figure 4.3 has been constructed to show a comparison of the responses between school A and B.

The graph below shows the learner's response (per school) to the five statements given in Table 4.3.

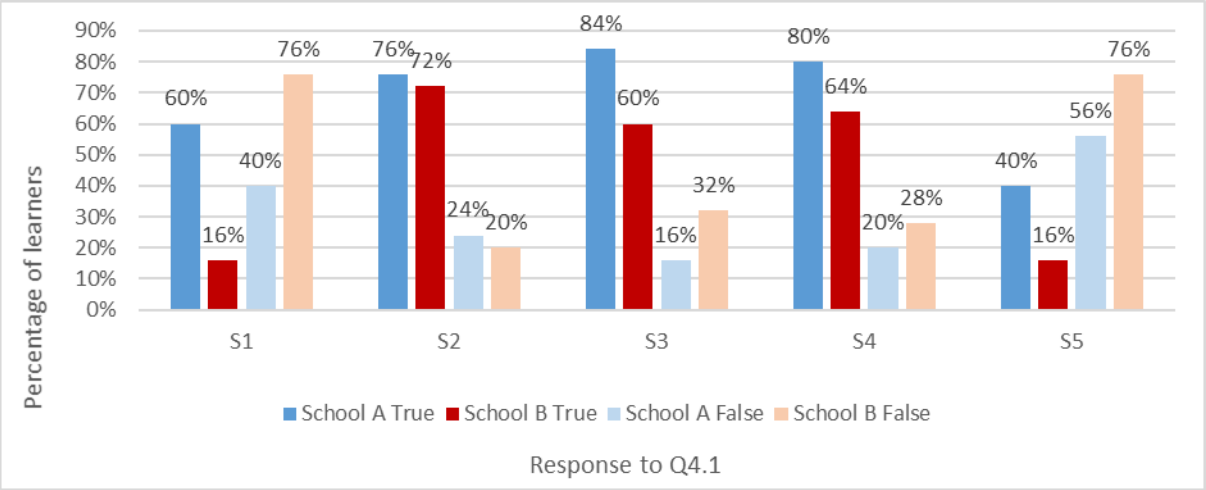


Figure 4.3: Responses to statements about biotechnology processes and genetic modification

The study of genetics involves several anchoring concepts such as cell structure, cell division, chromosome and genes (Sebitosi, 2007). In the grade 9 Natural Sciences curriculum in South Africa cell division is discussed very briefly while the plant and animal cell is done in detail, especially the structural and functional descriptions of the nucleus. Sebitosi (2007) used concept maps in her study on genetics and inheritance. The analysis of the concept maps revealed that learners had problems with genetic concepts i.e. the difference between chromosomes and genes and what is inherited and what is not. In this study question 2.1 was intended to find out if the learners heard of the terms mentioned above and question 4.1 entailed a reasoning aspect in which the learner could use the terms in the appropriate context to explain their understanding and knowledge of biotechnology. The different categories below illustrate the learners understanding and misconceptions of the terms when used in different applications of biotechnology.

4.3.1 Modifying or altering of genes

Statements 1, 4 and 5 are related to modifying and altering of genes for a specific purpose. A few responses for statement 1 have been highlighted below:

Statement 1

L1 A	*It is not possible for a plant to have genes.*	***Incorrect***
L14 A	*Ordinary tomatoes have genes while genetically modified tomatoes do not have genes.*	***Incorrect with misconception***
L2 A	*All tomatoes are the same.*	***Incorrect***
L20 A	*All tomatoes have genes because when all organisms reproduce - they pass on hereditary factors to their offspring.*	***Correct***
L6 B	*They used genes from ordinary tomato to modify other tomatoes*	***Correct***
L9 B	*Because if you plant the seeds of tomatoes, tomatoes will grow.*	***Correct***
L21 B	*Ordinary tomatoes have genes because it has micro-organisms.*	***Incorrect with misconception***

Statement 4

L13 A	*Because when changing the genes of certain plants it can influence growth.*	***Correct***

Statement 5

L8 A	*No, genes are our hereditary factors which cannot be changed.*	***Incorrect***
L9 A	*our genes cannot change.*	

In light of comments made by Sebitosi (2007), the above statements from learners clearly indicate that misconceptions related to genetic modification do exist. The responses given by the learners also indicate there is some prior or existing knowledge of genes despite the misconceptions or alternative conceptions. The reason given by learner L21B can be interpreted in terms of micro-organisms influencing the genes of tomatoes or if there were no micro-organisms there would be no genes. Clearly the learner's response shows evidence of conflicting ideas as well, e.g. plants not having genes or genetically modified tomatoes not having genes either. With respect to the response by learner L14A two aspects are communicated, firstly a misconception about genes and secondly a misunderstanding of genetic modification. The anchoring concepts here are genes as the learners seem to have an idea of what genes are in relation to their responses.

For statements 4 (A-80%, B-64%) and 5 (A-56%, B16%) the responses above indicate that learners are knowledgeable about the implications of gene alteration and they are aware that our hereditary characteristics cannot change. Statement 4 refers to changing of plant genes for the benefit of farmers. With our growing population farmers need to ensure that their yields are sufficient to sustain life and therefore scientists have made it possible due to manipulation

of favorable characteristics to benefit the farmer. Statement 4 shows a similar trend as in statement 3 with 80% of school A and 64% of school B answering correctly, showing that they ae aware of the uses of micro-organisms in biotechnology applications. Learners might have come across this information from their social science lesson or may be through documentaries presented by the media.

4.3.2 Biotechnology and Nature

The majority of the learners from both school A (76%) and school B (72%) answered true for statement 2 indicating that they are aware that biotechnology is a process that manipulates nature.

L17 A	*Biotechnology improves nature and makes it better and suitable for humans by doing the process.*	***Correct***
L20 A	*Biotechnology is a scientific way of speeding up growth of organisms or reproducing by chemicals reactions*	***Correct*** ***Incorrect****.*
L3 B	*the scientists interfere with nature by modifying the organisms*	***Correct***

In order for the growth of certain organisms e.g. chickens to grow faster they are injected with a growth hormone thus speeding up the growth process. The hormone might have been produced through a biotechnological process but the chicken is just merely injected with it. The response for L20A shows a misconception although the first part of the statement is correct but the second part is incorrect. The above statements presented by the learners clearly indicate that scientists have interfered with nature to improve the quality of life by modifying organisms and making them suitable for the benefit of humans.

4.3.3 Traditional practices in Biotechnology

Eighty four percent of the learners from school A answered true for statement 3 as compared to 60% of school B. It is clear that majority of the learners in both schools are aware of traditional biotechnology practices. School B is situated in a township area and learners may be making association with their real life experience, hence indicating that through interaction within their environment, knowledge is developed and linked to classroom practice. Yet fewer learners in school B gave the correct answer. This may have resulted from the learners not understanding the question. In school A, learner response was greater as learners might have learnt about traditional biotechnology practices in class.

L19 B Because in ceremonies it is used to make traditional beer.

L19B in his/her response shows the evidence of linking experience to knowledge. This learner might have been present at a ceremony at which traditional beer was being prepared.

According to Sebitosi (2007), in order for a learner to grasp concepts of genetic modification and biotechnology processes, it is necessary to have foundation knowledge on cells, genes, chromosomes and mitosis. The reason for this is that learners enter an instructional environment with pre-conceived existing ideas and would therefore have to assimilate the new information into their existing framework of knowledge (Ausubel, 1968).

4.4 ATTITUDES TOWARDS BIOTECHNOLOGY.

Research in other countries reveals that attitudes towards biotechnology depend upon the type of organism involved and the end product (Chen &Raffan, 1999; Dawson & Soames, 2006). Lock, Miles & Hughes (1995) claim that after intervention relating to biotechnology, the knowledge of 16 year old students significantly increased and their attitudes were more favorable. Chen & Raffan (1999) also found that students studying biology had a more positive attitude about biotechnology as compared to those not studying biology. Dawson & Schibeci (2003) also indicated that a greater awareness of biotechnology resulted in more positive attitudes towards applications in biotechnology. In this study learners showed a diversity of ideas which influenced their attitudes towards biotechnology and these attitudes have been investigated using question five (Appendix 1).

Question 5 has 8 statements that are related to genetical engineering such as altering of genes to improve the taste and quality of foods as well as the use of the embryo to treat genetic disorders. The intention of this question was to find out whether grade 9 learners found these applications acceptable or unacceptable. Table 4.4 and figure 4.4 below show the results of the learners' responses. The responses of the learners from both schools did not appear to differ markedly. For the purpose of reporting the results and discussing the analysis, Question 5 will be divided into the three categories listed below and the graphical representation of the data will be given per category.

4.4.1 Genetical engineering using micro-organisms

4.4.2 Genetical engineering through alteration of genes

4.4.3 Genetical engineering through inserting genes either in plants or animals.

A summary of the responses are captured in table 4.4 showing that learners have different attitudes towards different biotechnology processes.

Table 4.4: learners' attitudes towards biotechnology practices (N=25 school A and N=25 school B)

Statements	No. of Learner Responses					
	Acceptable		Unacceptable		No Response	
	A	B	A	B	A	B
1. Using genetically engineered micro-organisms to enable more efficient breaking down of human sewage.	18 (72%)	18 (72%)	05 (20%)	6 (24%)	2 (8%)	01 (4%)
2. Changing the genes of plants so that they will grow better in salty soils.	16 (64%)	21 (84%)	8 (32%)	4 (16%)	01 (4%)	0 (0%)
3. Altering the genes in an embryo to treat a genetic disease.	17 (68%)	18 (72%)	7 (28%)	7 (28%)	01 (4%)	0 (0%)
4. Adding genes to plants to increase their nutritional value.	16 (64%)	22 (88%)	8 (32%)	3 (12%)	01 (4%)	0 (0%)
5. Altering the genes in fruit to improve their taste.	9 (36%)	10 (40%)	15 (60%)	14 (56%)	01 (4%)	01 (4%)
6. Inserting genes from micro-organisms into crops to provide pesticide resistance.	13 (52%)	14 (56%)	10 (40%)	11 (44%)	2 (8%)	0 (0%)
7. Inserting genes from plants to animals.	2 (8%)	8 (32%)	21 (84%)	16 (64%)	2 (8%)	01 (4%)
8. Adding genes to yeast that is then used to make better tasting bread.	9 (36%)	19 (76%)	14 (56%)	6 (24%)	2 (8%)	0 (0%)

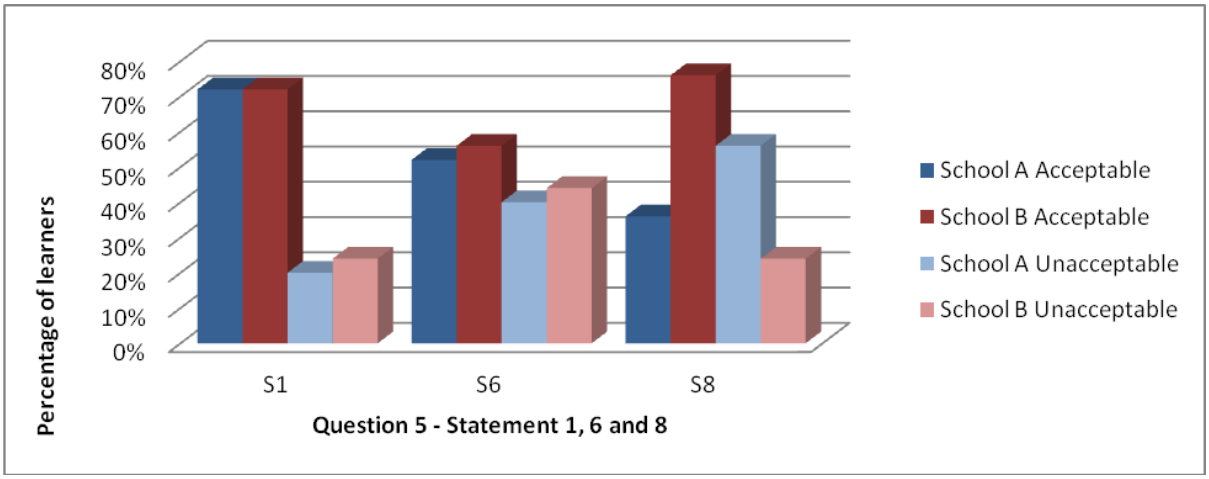


Figure 4.4: showing the responses for learner's attitudes towards biotechnology applications using micro-organisms

4.4.1 Genetical engineering using micro-organisms

Statements 1, 6 and 8 relate to biotechnology processes involving micro-organisms. Most learners from school B found that the use of biotechnology processes involving micro-organisms, plants and including crops generally acceptable. For both schools (statement 6) over 50% of the learners accepted the use of micro-organisms in providing pest resistant crops. However, for statement 8, 76% of the learners in school B were in favour of adding genes to yeast to improve the taste of bread as compared to 56% of learners in school A, who found this to be an unacceptable practice.

Micro-organisms and sewage treatment

In both schools 72% of the grade 9 learners indicate that the use of genetically engineered micro-organisms is acceptable, indicating a positive attitude. The responses below indicate that most learners are in favour of preventing further pollution, thus indicating that there is a degree of consensus with respect to preventing further pollution of the air and land. Sewage left unattended takes a long time to breakdown on its own and therefore by using micro-organisms it speeds up the process. By breaking down the sewage effectively certain nutrients can be recycled and illnesses and harm to the environment can be avoided.

L17 A	*There will be less waste that causes pollution and harms humans and the environment.*	***Acceptable***
L2 B	*Because the sewage will affect the plants and human and the ozone layer.*	A***cceptable***

Pest resistant crops (statement 6)

The introduction of high-yielding crop varieties combined with high usage of synthetic fertilisers, pesticides, and the use of irrigation systems, transformed agriculture in many countries such as Asia, Latin America and Africa (Birch & Wheatley, 2005). However, in many cases the initial success of the crop varieties decreased very quickly. The contributing factor for this underachievement was the over-use of non-selective pesticides on pest-susceptible crop varieties. This increased the rate at which the insecticide-resistant pests evolved. It was through this evolutionary process that important biocontrol agents from the agricultural ecosystems were removed and in turn contributed to the successive increase of the primary and secondary pests (Birch & Wheatley, 2005). It was during the 1980's when scientists started to manipulate the genes of crop varieties with the aim of solving the pesticide problem. This is when genetic modification assisted in tailoring the crop to address the issue of the pest (Birch & Wheatley, 2005). According to figure 4.4, over 50% of the learners from both schools show a positive attitude towards this application of inserting genes from micro-organisms. Information about micro-organisms and pest control is discussed extensively in grade 11 Life Sciences. However, in grade 8 and 9 learners are merely informed of pests in terms of their ecological role in the ecosystem. Below are a few responses from the learners in both schools.

L25B	*because farmers like to see that crops growing and not eaten and making money for them.*	***Acceptable***
L4 B	*pesticide help to kill insects which eat crops*	***Acceptable***
L15 B)	*because if there is no pesticide resistant pests will eat the plant and the plant might not grow well or die.*	***Acceptable***
L8 A	*could decrease the loss of crops*	***Acceptable***
L2 A	*I don't know what's that*	***Unacceptable***

From the above the first four statements of learners show awareness of the benefits of the pesticide resistant crops and the fact that it could prevent loss of the crop for farmers. As indicated in table 4.4, fewer than 50% of the learners for both schools found the use of pest resistant crops unacceptable. Learners (A-52% and B- 56%) who approve of pesticide resistant crops probably acknowledge the greater need for a larger production to sustain the

growing population while learners (40% and 44%) who disapprove of its use are probably aware of the side effects it may have on other organisms as well as humans. However, the last response (L2A) also indicates that the learner has no knowledge of what pesticides are. This is an implication that the learner may have not encountered such information in their instruction.

Adding genes to a micro-organism (Statement 8)

Yeast cells have the ability to respire anaerobically thereby producing carbon dioxide to make the bread rise. The making of bread is considered to be a traditional practice of biotechnology. This statement (statement 8) is related to adding a gene to the yeast to improve the taste of the bread. The response from the learners for statement 8 show two extremes i.e. the majority of school A grade 9 learners (56%) found this practice unacceptable while majority of school B grade 9 learners (76%) found this practice acceptable. This could probably be the case since the environment which they come from play a major role. School B is in the township and could be because their everyday diet consists mainly of bread as many of the learners gave bread as an example, while school A learners might be exposed to a variety of foods or could very well be the influence of the teacher in the classroom. Below are some of the reasons for school B not accepting the addition of genes into yeast cells.

L25B	*because genes may have some side effects on the person who eats the bread.*	***Unacceptable***
L19 B	*No 'genetic 'improvements' should be made on living organisms.*	***Acceptable***
L6 B	*because sometimes we need bacteria to survive*.	**Unacceptable**

Here the learner L25B, has indicated his/her concern about side effects that a person might experience after consumption of the bread in which the yeast cell have been modified. For the second response the learner stands firmly against the interference of living organisms and their genetic composition. Learner L6B on the other hand has confused yeast cells with bacteria, however does indicate that they have a purpose as micro-organisms, but the statement is not acceptable because of the confusion. Knowledge of micro-organisms and the

confusion of bacteria and yeast cells could be used as anchoring concepts to explore further understanding of what the learner already knows.

4.4.2 Genetical engineering through alteration of genes.

Statements 3 and 5 relate to biotechnology applications that involve altering of genes for the purpose of treating genetic disorders or diseases and in the case of fruits increasing their nutritional value. The graph shows the responses of the learners.

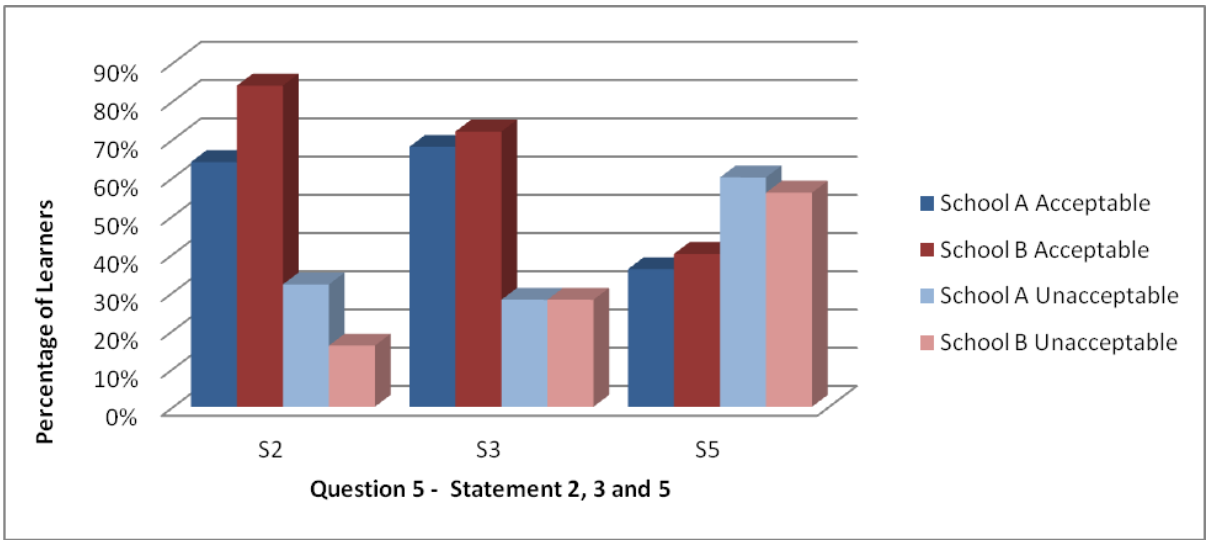


Figure 4.5: Showing the responses for learners' attitudes towards biotechnology applications through alteration of genes

The majority of the learners for statement 3 (A-68% and B-72%) in both schools were in favour of altering the genes in the human embryo for the treatment of genetic diseases. On the contrary Dawson & Soames (2006) report that far less learners (50% -55%) in Australia accept altering of genes in embryos. Below are some responses from the learners at both schools who felt that altering the genes was unacceptable.

L23 A	*I don't know*	***Unacceptable***
L16 A	*If something goes wrong then it would be like taking away someone's life*	***Unacceptable***
L3 A	*what if it has side effects*	***Unacceptable***
L8 B	*it can harm or kill the embryo*	***Unacceptable***
L9 B	*it won't be accepted because people could die from that disease*	***Unacceptable***
L17 B	*The embryo cannot treat a genetic disease.*	***Unacceptable***

Although the majority of the learners were in favour of altering the genes of the embryo, the above responses indicate that these learners are concerned about the use of embryos for testing of genetic diseases. Deoxyribose nucleic acids (DNA) provide life its blueprints for survival. Humans have a wide variety of DNA sequences and DNA condenses to form chromosomes. Humans have 46 chromosomes in each cell and each chromosome is made up of thousands of genes for specific structural and physical characteristics of an individual. Sometimes genes may be problematic due to mutations occurring and therefore result in diseases such as cystic fibrosis and Down syndrome. Through careful and calculated research scientists have found a way to prevent such abnormalities by analysing the DNA of that single cell (Pray, 2008). Scientists have developed a treatment called gene therapy that involves the altering of genes in body cells (somatic cells) or embryonic cells. Once the DNA has been analysed, it is that portion that is problematic that is removed and replaced by normal genes thus preventing the abnormality from being present in the offspring. There are two reasons why such testing is important, the first being to diagnosis a genetic disease or disorder and the second being to assist an ailing sibling. Genetic testing is a very controversial issue and raises many questions in society. In this research fewer learners (28% for both schools) find this application unacceptable.

It is clear from the responses to statement 3 that indeed some learners are not knowledgeable about stem cell research. Learners [L16 A, L3 A, L8 B and L9 B] suggest that there are ethical reasons why such research is not viable. Their concerns relate to loss of life and side effects. The fact that they have made the above comments is an indication that they have thought about the effects of such research and how it could impact on the larger society. The last statement for learner L17B shows that the learner has some knowledge but some misunderstanding exists as he or she is assuming that it is the embryo itself that is used to treat the disease, when in fact it is the embryo that provides the diagnosis which is an indication of a particular genetic disorder and that has to be treated accordingly.

In comparison to altering the genes of an embryo the attitude towards altering genes in fruit (statement 5) is by far less acceptable (36% to 40%) in both schools. The responses from two of these learners is an indication that there has been careful thought with respect to the

biotechnology application as they are able to relate possible problems that could result from the application.

L25 B	*because some of us people are now getting allergic to a lot of foods because of the genes of cells used in the foods.*	***Unacceptable***
L18 A	*Adding flavourings can make it dangerous and cause new diseases.*	***Unacceptable***

Both learners have taken into account the effects of altering the genes and therefore show a more negative attitude towards the application. In this study, statement 2, i.e. changing genes of plants so that they would grow better in salty soils is acceptable (A-64% and B-84%).

4.4.3 Genetical engineering through inserting genes either in plants or animals.

Traditional breeding practices (selective breeding) of altering the genome of plants and animals have been practiced for many years. Artificial selection of desired characteristics in organisms resulted in a variety of different organisms' e.g. sweet corn, thus increasing the gene pool of the organism (Philips, 2008). Since the introduction of the field of genetic engineering, genes from one species can be introduced into another. With recombinant DNA technology, bacteria were used to produce vitamins, proteins, hormones and antibiotics (Isaac, Chetty, Manganye, Mpondwana & White, 2013). DNA from *E. coli* bacteria was removed. An enzyme was used to cut open the bacterium DNA. A portion of the DNA code for human insulin was inserted into the *E.coli* DNA and the DNA was put back into the bacterium to produce insulin used for the treatment of diabetes. Recombinant DNA technology is introduced in the grade 11 Life Sciences curriculum.

In this study adding genes to increase the nutritional value of plants (A–64% and B-88%) is acceptable while far fewer learners (A-8%) and B-32%) consider inserting genes from plants into animals acceptable. This is shown in the graph below.

L13 B	*Because plant and animal is not the same and inserting genes from the plants to the animals will not be a proper thing.*	***Unacceptable***

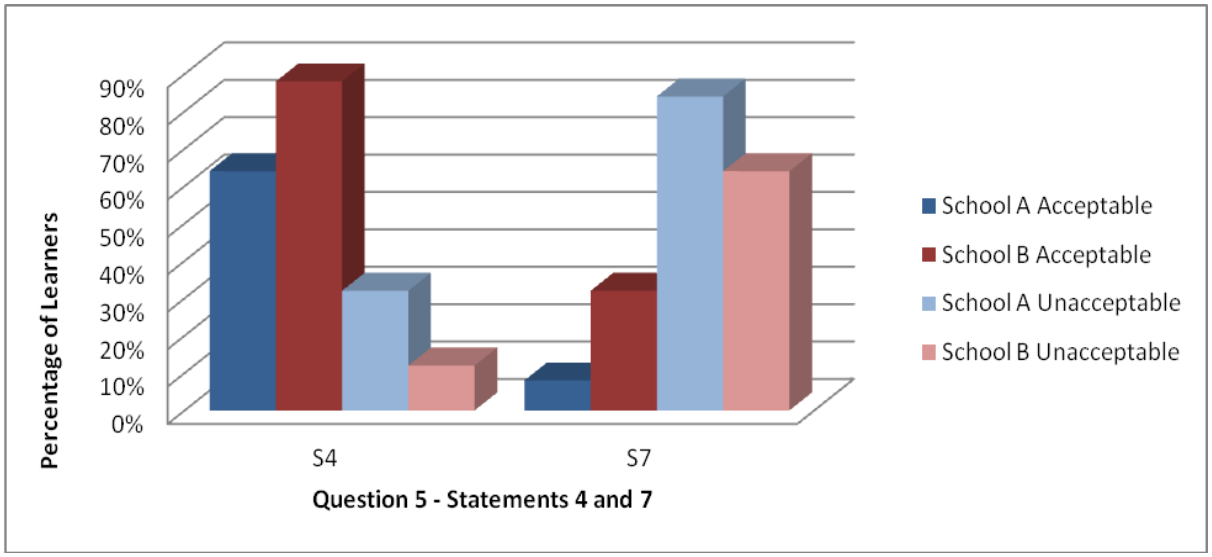


Figure 4.6: showing the responses for learner's attitudes towards biotechnology applications through inserting genes either in plants or animals for specific characteristics

The above learner expresses his /her view by indicating that they may be incompatible and it may be unethical to carry out such a practice therefore it is unacceptable.

Dawson & Soames (2006), in their study also report that learners were less favorable towards the inserting of plant genes into animals i.e. (40%) before the intervention and far less (31%) after intervention.

4.5 Sources of information about Biotechnology

Question 2.2 was intended to find out which source of information was used the most to find out information about biotechnology. The average percentages for each source of information for both schools are shown in Table 4.5 and figure 4.7. Codes are given for each of the sources of information so that they can be easily represented on the graph.

Table 4.5: Table showing learners response to sources of information about Biotechnology

Question 2.2	Cloning		GMO		GENES		DNA		STEM CELL RES		AVERAGE	
Sources of information	A	B	A	B	A	B	A	B	A	B	A	B
Teacher (T)	8	9	16	6	12	22	11	19	9	6	45%	50%
	32%	36%	64%	24%	48%	88%	44%	76%	36%	24%		
Internet Access (IA)	7	6	11	5	7	7	9	5	9	6	34%	23%
	28%	24%	44%	20%	28%	28%	36%	20%	36%	24%		
Media presentations on TV & radio (M)	8	14	7	6	6	11	7	11	3	3	25%	36%
	32%	56%	28%	24%	24%	44%	28%	44%	12%	12%		
Parents & Guardians (P&G)	7	5	3	2	12	11	6	13	2	2	24%	26%
	28%	20%	12%	8%	48%	44%	24%	52%	8%	8%		
Friends (F)	2	10	5	3	2	10	3	7	2	1	11%	25%
	8%	40%	20%	12%	8%	40%	12%	28%	8%	4%		
Grand Parents (GP)	5	3	3	2	3	9	4	6	1	0	11%	16%
	20%	12%	12%	8%	12%	36%	8%	24%	4%	0%		
Magazines you have read (M)	2	8	3	0	3	8	7	6	1	0	13%	18%
	8%	32%	12%	0%	12%	32%	28%	24%	4%	0%		
Others (O)	3	3	3	2	5	4	5	4	3	0	15%	7%
	12%	12%	12%	8%	20%	8%	20%	8%	12%	0%		

(N=25 school A and N=25 school B)

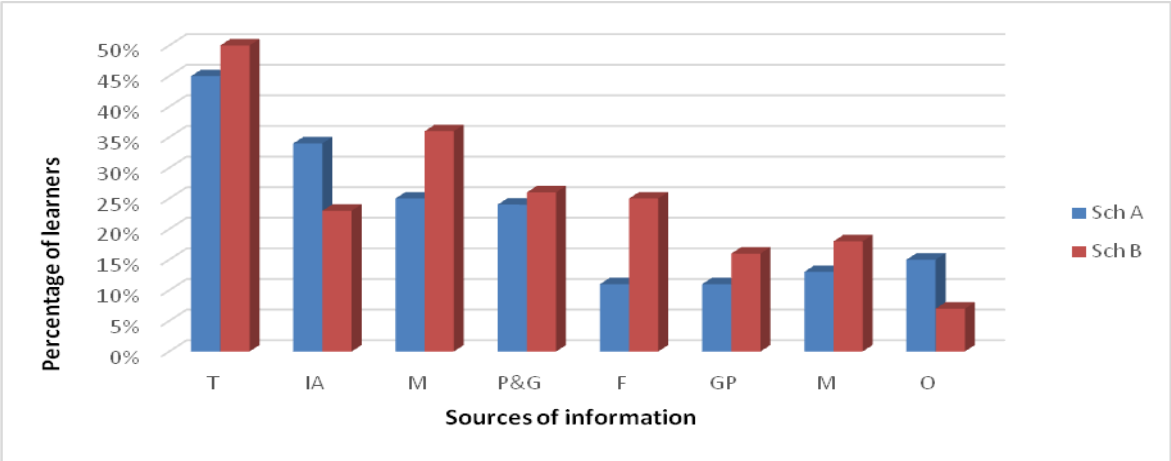


Figure 4.7 showing the average percentage of sources of information for school A & B

The average results show that for each of the five terminologies represented in question 2.2; the most common source of information is the teacher (A-45% and B-50%). Interestingly the grade 9 learners from school A show a greater average percentage of internet usage (34%) as compared to school B which shows a greater usage of media presentation (36%). For school A apart from the teacher as a source, learners obtain their information about genes, GMO, DNA and stem cell research by using the internet, media, parents and guardians. School B learners on the other hand get the information about genes and DNA mainly from the teacher, DNA and cloning from parents and guardians and the media. The learners from School A get information about GMO and stem cell research mainly from the internet.

Different sources of information with regards to biotechnology have been researched to some extent (Lock & Miles, 1993; Lock, Miles & Hughes, 1995; Gunter, Kinderlerer & Beyleveld, 1998). According to Lock & Miles (1993) and Lock et.al, (1995) genetic engineering received wide coverage by the media. In the study conducted by Gunter et.al, (1998) teenagers mentioned that TV news and documentary programmes as the most informative (52%), news papers and magazines (33%) and teaching at school (29%) while in this study the most frequently mentioned source of information in both schools is the teacher, followed by the media and the internet. Gunter et.al, (1998, p.110) also claim that,

> Young *people regard formal schooling in science as an important source of their current science knowledge. Indeed it may be that many young people expect to have their science awareness raised at school.*

In light of the above statement and the aim of my research study it is clear that the science curriculum at grade 9 level should include biotechnology not just in terms of career choice but rather to enlighten and broaden the knowledge of what biotechnology entails in the broader context.

Summary of the possible anchoring concepts identified from learners' prior knowledge

Grade 9 learners have knowledge about biotechnology that can be used as anchoring concepts that teachers at grade 10 level can tap into during the teaching of biotechnology. Throughout my analysis of the learner's responses it became evident to me that learners have knowledge of genes, bacteria and yeast as micro-organisms and cloning. The knowledge pertaining to bacteria and yeast is misconceived in terms of the genes present within them bringing about the desired effect when it is used in the production of cheese or the making of bread. The educator can use this information as the starting point, explaining to the learner what micro-organisms are and how they are used in relation to genetic engineering. These anchoring concepts could then form the basis for understanding related biotechnology applications.

Summary of the attitudes that learners in this study had towards biotechnology

Learners from both schools hold a wide range of attitudes towards biotechnology. In cases where learners felt the altering of genes to be beneficial, they showed a more positive attitude, for example changing the genes of plants so that they grow better in salty soils. Many of the learners indicated that altering genes of organisms had many side effects and showed a negative attitude towards the application. Learners develop a certain attitude based on what they have learnt and already know. Therefore, teachers must be aware of the learners' attitudes as this may interfere with their acquisition of new knowledge.

4.5 CONCLUDING REMARKS

The analysis and discussion of results compiled in this chapter shows that grade 9 learners do have some understanding and knowledge of biotechnology and its practices. This study also shows that many grade 9 learners are able to express their knowledge of biotechnology by providing reasoning for their choices in question 4 and 5 of the questionnaire. A few learners also indicated that they do not know what is being asked of them and this might have resulted either from the fact that majority of the learners in both schools are second language learners and are unable to comprehend or understand the question or they simply did not know about the biotechnology practices that they were being questioned about. Question 5 addresses issues of attitudes towards biotechnology and this study has shown that majority of grade 9 learners are aware of biotechnology applications and its influence on our daily lives. Some learners were able to elaborate on how they understood biotechnology, generally accepting modification to plants rather than animals. Most importantly the first point of contact for their information is the teacher and this is clearly indicated in table 4.5. In the next Chapter the conclusion from the study, implications and recommendations are discussed

CHAPTER FIVE

Conclusion, Summary and Discussion of the Findings and Recommendations

5.1 OVERVIEW OF THE CHAPTER

This research study focused on the knowledge of and attitudes of South African grade 9 learners, towards biotechnology. The target population was grade 9 learners as they are in a transition phase between General Education and Training (GET) and the Further Education and Training (FET) phase. In Life Sciences biotechnology is taught in depth from grade 10 to grade 12. In grade 10, the topic biotechnology is included under the topic of cell division and includes stem cell research as well as career opportunities. Biotechnology progressively continues in grade 11 and 12 Life Sciences. In grade 11 the focus is on traditional and medical practices of biotechnology, such as the making of cheese, bread, beer and antibiotics while in grade 12 it focuses largely on genetic engineering i.e. identifying genetic disorders, forensics science, cloning and genetic modification.

This chapter begins with the summary of the findings i.e. a summary of the learners' knowledge and attitudes towards biotechnology. The limitations of the study are then presented. The learners' misconceptions about biotechnology will also be highlighted. Finally, recommendations and implications for further study will also be discussed.

5.2 Summary of the findings.

A detailed discussion of the results is presented in chapter 4. This section provides a summary and discussion of the findings obtained when seeking answers to the research questions below:

(i) What existing knowledge do grade 9 Natural Sciences learners have about biotechnology?

(ii) What are the attitudes of grade 9 Natural Sciences learners towards biotechnology?

The first question was designed to establish or identify if the learners had prior or existing knowledge of biotechnology and if so to what extent i.e. were the learners able to explain

biotechnology in depth or were they able to give a surface meaning or a brief understanding of what biotechnology is.

The second question was designed to find out about the learners' attitudes towards biotechnology since they would make important decisions about the use of products of biotechnology.

5.2.1 Knowledge and understanding about biotechnology

It is important that the knowledge and understanding of biotechnology among learners be known as it plays a pivotal role in determining what needs to be taught and at which point in the curriculum. The analysis of the results for the knowledge based questions reveal that grade 9 learners do have existing knowledge of biotechnology. Some learners (Table 4.1) were able to identify the correct biotechnology product and were able to indicate the micro-organism used in its preparation.

In question 3 the concept cloning was discussed and between the two schools, school B identified the calf as being a clone of the mother, however as indicated in chapter 4, 4.1, the explanation was relatively confused. Learners 17A and 20 B seem to indicate that the calf is not clones as the positioning of the spots are different for the mother and the calf. Therefore I was able to conclude that the learners from both schools do have knowledge about cloning and while some learners are able to explain the understanding others show that some misconceptions also exist. While respondents in school A, on the other hand show distinctly that the calf is not a clone, some learners (n=6) indicated that they do not know.

Although learners answered correctly their reasoning indicated that their knowledge of biotechnology is limited because many misconceptions were evident through the analysis as pointed out in chapter 4. The most common misconception relates to genes of an organism in relation to genetic modification and gene alteration. While this definition (Biotechnology is the practical use of biological systems to produce goods or products and it includes transformation of materials by micro-organisms (e.g. Fermentation), methods of propagation such as plant cloning or grafting, may involve genetic alteration (modification) through selective or artificial breeding.) may be correct, it is a concern that learners might have shared information with each other. Additional to figure 4.3 and table 4.3, there was question 4.2 which required a definition of biotechnology for example; learners from school B defined biotechnology as '*using bacteria, fungi, and cells from plants and animals for scientific purposes'*. The majority of the learners

provided text book responses and this shows that there could have been a discrepancy or the learners could have at some point learnt about biotechnology in that manner providing their own understanding.

Generally there wasn't a marked difference between the two schools with respect to their responses in the questionnaire and in both schools learners were able to provide many examples of genetic modification of plants rather than animals. However, comparing this study to Dawson & Schibeci (2004) 20-30% of the Australian learners in the study were unable to give examples of genetic modification, genetic engineering or cloning. In my research study learners from both schools (A-56% and B-52%) were able to give a clear definition of biotechnology for question 4.2 while 24% of the learners in school B had given the exact same answer for the same question. In Dawson & Schibeci's (2003) study of 15 year olds from 11 Australian schools it is stated that learners showed confusion about the difference between GM foods and foods through selective breeding and hence these learners show very little understanding of biotechnology. This research study shows a similar trend in that some learners (32%) also showed confusion in their responses and 8% said that they did not know or they do not understand.

5.2.2 Attitudes towards biotechnology

The intention of question 5 (Appendix 1) was to determine what attitudes learners had about biotechnology and how it relates to their daily life experiences. Generally learners had a more positive attitude towards the manipulation of genes in plants as compared to animals. For both schools A and B, statements 1 to 4 showed a greater percentage of positive attitudes as indicated in chapter 4. Learners from both schools show 50% acceptability for the use pesticide resistant crops. For statement 1 and statement 8 learners from school B maintained a positive attitude towards the use of micro-organisms to improve sewage treatment and better tasting bread while school A showed a positive attitude towards sewage treatment but a negative towards improving the taste of bread. In terms of this study, it is clear from school A that it is acceptable to use micro-organisms for certain applications of biotechnology and not in others. Other studies such as those conducted by Dawson & Soames (2006) and Dawson & Schibeci (2003) show similar results and also conclude that there isn't a marked difference in the attitudes of learners towards biotechnology application. These results could probably be similar as the learners in my study and the learners in the above mentioned studies were

between the same age groups. It could also be that in both studies that the learners were not yet involved in biology courses or had any form of intervention about biotechnology.

5.2.3 Misconceptions associated with biotechnology

In the recent years many science researchers have focused on learners and university students' conceptual development and cognitive processes (Smith et. al. 1994; Kwon & Lawson, 2000). Each learner has a different cognitive structure because of their different ability levels, backgrounds and attitudes (Piaget & Inhelder, B, 1969). It is because of these differences that learners have a diverse world view of what biotechnology is and how its applications influence our daily lives. Misconceptions, misunderstanding or alternative conceptions can be linked back to the conceptual framework underpinning this study i.e. the theory of subsumption. Through interaction and instruction learners already have prior knowledge. As new information is learned on a daily basis, learners tend to commit this learned information in the direction of their beliefs and pre-conceived ideas or existing knowledge. If the prior or existing knowledge is not consistent with what is scientifically acceptable in this case, then it is considered to be an alternative conception or a misconception.

During the course of this study many misconceptions relating to biotechnology surfaced. For example, learners indicated that genetically modified tomatoes do not have genes and neither do plants in general. Concepts such as chromosomes, cell division, cells, DNA and genes need to be taught adequately to develop a solid foundation of understanding. The analysis of the responses show misunderstanding probably due to poor or insufficient knowledge about genes and their location within a cell. Another misconception is related genetic modification. The misconception is that consumption of genetically modified (GM) foods will result in changes of the genetic constitution of human genes. 40% of the learners in school B agree that human genes will change if a GM apple is eaten. This could possibly be due to insufficient knowledge about genetic modification and hence the misunderstanding. In grade 9, learners are taught about the cell and the nucleus, explaining the importance of DNA and genes, however insight as to how genes may play a role in genetic engineering is not explained in depth. Therefore, much of what is understood about genetic engineering and biotechnology including their applications is through the media and documentaries.

5.2.4 Sources of information about biotechnology.

Learners acquire their knowledge of biotechnology from various resources. In this study, the intention of question 2 was to determine which resource is mostly used. Learners were given eight alternatives and the most favoured resource option was teachers, with the internet, media presentations and parents following in that order. On the contrary, in another study in Britain, Gunter et. al. (1998) show that the most mentioned source of information is TV news and documentaries with the least acquired information source being teaching at school. This could probably have resulted from the fact that South African learners rely more on their teachers as certain technological equipment may not be readily available to the majority of learners while Britain is a technologically advanced country. It is only a select few that may have the means to up to date technology and therefore are able to use other sources for information.

5.3 LIMITATIONS OF THE STUDY

As with any other field of research, this study had limitations due to circumstances beyond the researcher's control. Such factors may result in threats to validity of the findings and conclusions drawn from the findings. The limitations of this study and the necessary actions that were taken to minimise the limitations are discussed below. It is important for the reader to be aware of the limitations so that the limitations can be taken into consideration when looking at the conclusion.

5.3.1 Design of the questionnaire

In my study it was imperative to conduct a pilot-test as the questionnaire had to be designed since I was unable to source a questionnaire that had been used in a previous study. However, questions from other studies were adapted in the questionnaire that was designed for the purpose of this study (Dawson & Soames, 2006). The limitation is that I was restricted to using certain questions as I had to take the level of understanding of the learners into consideration.

In this research study, grade 8 learners from the same school (school A) were used in the pilot study. It did not occur to me at that point that the learners who volunteered to participate in the pilot study could have been friends of the grade 9 learners and may have discussed the instrument. Although the instrument was also face validated by a science education expert (lecturer at WITS) and my Life Sciences colleague at the school where I teach, certain

problems became evident in the questionnaire design, for e.g. statement number 7 of question 5 indicates a limitation as it did not provide an example for plant genes being inserted into animals and the learner's confusion was conveyed in their responses. Unfortunately this error was only noticed when the researcher was consolidating data from both schools.

5.3.2 Possible problems of learners responding with ideas other than their own.

One of the limitations is the fact that the researcher could not be present in every class when the learners were completing the questionnaire. As a result the certainty of lack of consultation between the peers cannot be guaranteed. Learners could have asked their peers for assistance as repetition of the responses are evident in the reasoning aspect for question 4 and 5. An attempt to curb this problem was made at the start of the session but obviously learners found some means of communicating their ideas. The unfortunate part about this is that at the stage of analysis very little could be done to address the issue and I had to keep in mind that when a learner presented someone else's ideas, it affects the validity of the results. Besides listing someone else's ideas there are many learners who had no responses to the reasoning aspect making it difficult to assess what their attitudes were.

5.3.3 Use of convenience sampling

In this study, although 360 learners combined from both schools answered the questionnaire, only a small minority consented to the researcher using the data they provided, hence the data was gathered from a convenience sample. This type of sampling is probably not a true reflection or representation of the target population. Since the research took place in only two schools in Gauteng and in those schools, only the minority gave consent for the use of the information they provided, the results cannot be generalised to all South African grade 9 learners.

5.4 RECOMMENDATIONS

5.4.1 For the Department of Education – Curriculum development

The increased public awareness of the significance and necessity of biotechnology has encouraged educators to implement biotechnology instruction in various educational settings. Research shows that although technology educators have gone a step further by focusing on

biotechnology as a content organiser for the technology education program, biotechnology has not been broadly implemented in technology education programs (Brown, Kemp & Hall, 1998; Rogers, 1996; Russell, 2003; Sanders, 2001). In a study in Korea, Korean technology educators saw the benefits of biotechnology in their student's lives and the need to teach biotechnology content in a technology class (Kwon & Chang, 2009).

The curriculum content for Natural Science grade 9 should be revisited as biotechnology is discussed in terms of career options rather than focusing on developing an understanding of the concept of biotechnology and its applications. Learners need to develop a sound understanding of biotechnology as they would need to make important decisions regarding the use of biotechnology products in their daily lives. Being knowledgeable and literate about biotechnology will also help understand the necessity of such products as the dimensions of our world continue to change and evolve from the "green revolution to the gene evolution."

With the goal to help individuals become scientifically and technologically literate, some of the most important science education is to make sure that learners and students learn to understand the natural world around them. Current trends in research show that biotechnology and genetic engineering have considerably improved issues such as drug production (antibiotics and insulin for diabetes), criminal DNA finger printing or profiling (forensic science), cloning, gene transfer and the human genome project and nutrition production.

In my experience as an educator the content relating to biotechnology is very fragmented as all of the above mentioned technologies are only dealt with in grade 12 and there needs to be continuity from grade 9 into the senior phase. Clear and concise information should be available to educators so that the correct information can be imparted. Therefore, the Department of Education should consider providing training in this regard so as to equip educators to impart the relevant current information.

5.4.2 To the Witwatersrand University education methods advisors

Regular workshops could be held to inform the students and Life Sciences educators of current information and biotechnology research to keep them abreast and globally competitive. The advisors could work in collaboration with the schools so that there could be consistency between the schools and the university, making it more relevant for prospective students that will enter the field of science.

5.4.3 Recommendations for further research

For a further study, it would be relevant to do a cross sectional study between the three grades of the FET phase using a specific group of learners and incorporating an intervention strategy. This will help to further link between the GET and FET phase and also reveal the progression as well as change in understanding and attitude towards biotechnology.

5.5 CONCLUDING REMARKS

This study has shown that grade 9 learners do have existing knowledge of biotechnology. The knowledge that they have, has led them to possess certain attitudes towards biotechnology applications. This knowledge would not only assist curriculum designers but also Natural Sciences and Life Sciences educators giving them insight as to how they can approach teaching of biotechnology in the classroom.

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APPENDIX: 1 QUESTIONAIRRE

Purpose of the Questionnaire

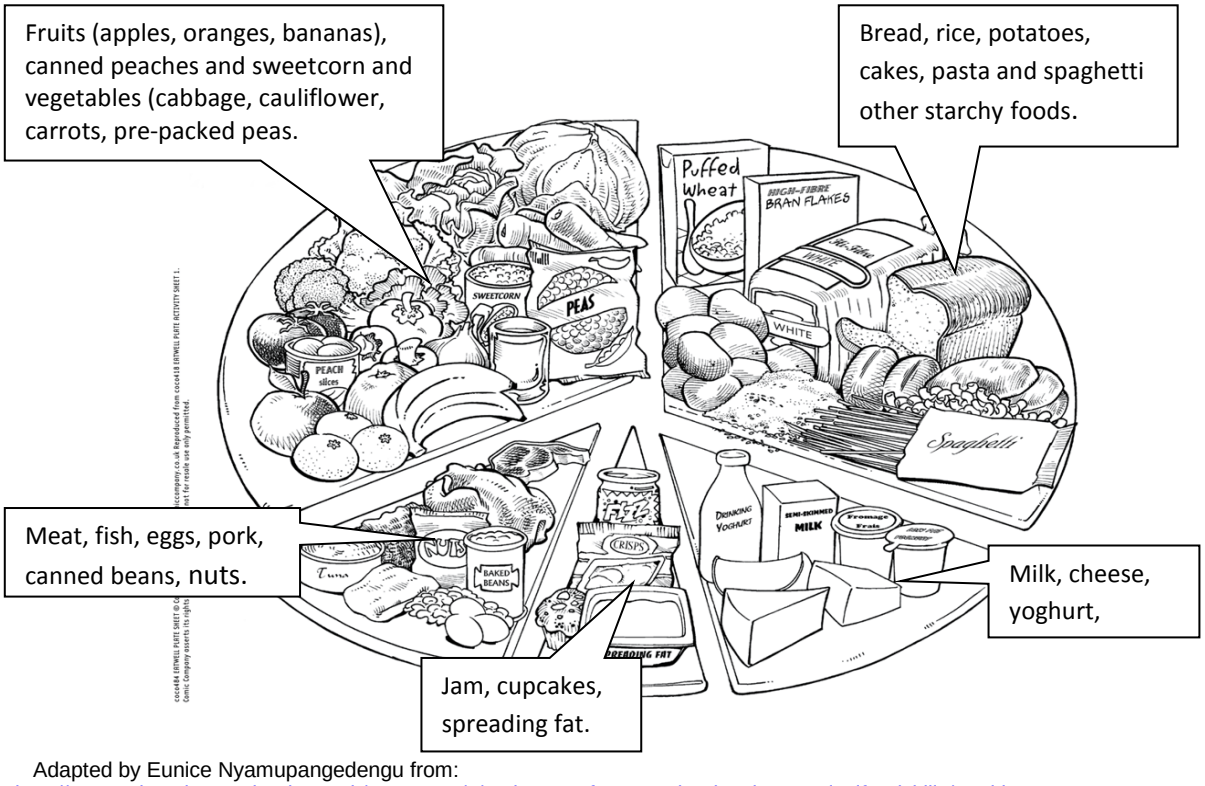
The purpose of the questionnaire is to find out what ideas you have about biotechnology.

INSTRUCTIONS:

1. **Read the questions carefully and answer all the questions in the questionnaire.**
2. **Please write clearly and legibly.**

QUESTION: 1

The diagram below is a plate showing a variety of foods. Identify any foods produced with the aid of biotechnology. In each case suggest a reason for including it as a product of biotechnology. Write your answer in the table below.



Adapted by Eunice Nyamupangedengu from:
http://www.educationscotland.gov.uk/resources/c/cpdsupportframeworktodeveloppracticalfoodskills/nutrition.asp

Type of food	Reason for including it as a biotechnology product

QUESTION: 2

2.1 Have you heard of the terms listed below? Indicate your answer by placing a tick (√) in the appropriate space provided.

TERMS

1. Cloning	☐ **YES**	☐ **NO**
2. Genetically modified organisms	☐ **YES**	☐ **NO**
3. Genes	☐ **YES**	☐ **NO**
4. Stem cell Research	☐ **YES**	☐ **NO**
5. DNA	☐ **YES**	☐ **NO**

2.2 Tick (√) in the spaces provided in the table below to let me know where or how you may have heard of the above terms. You may choose more than one option.

Did you hear these terms from:	Cloning	Genetically modified organisms	Genes	DNA	Stem cell Research
Teachers					
Friends					
Parents, guardians					
Grand parents					
Internet access					
Magazines you have read					
Media presentations on TV or radio					
Other					

QUESTION: 3

3. Look at the diagram below that shows a cow and its calf.

3.1.1 Do you think the calf has been cloned? Tick **(√)** the block of your choice.

YES ☐ **NO** ☐ **I DON'T KNOW** ☐

3.1.2 If your answer is YES or NO, give a reason for your choice.

_____
_____
_____

QUESTION: 4

The statements below about biotechnology and its uses are either True or False.

Read the statements and put a tick (√) in the space provided and give a reason for your choice.

Statement	True	False	Reason
1. Ordinary tomatoes do not have genes while genetically modified tomatoes have genes.			
2. Biotechnology is a process that interferes with nature			
3. Making traditional beer and bread using yeast cells is a biotechnology process.			
4. Scientists have changed the genes of certain plants for the benefit to farmers.			
5. If a person eats a genetically modified apple, their own genes can be changed.			

4.2 What is Biotechnology? (How would you explain biotechnology to a friend?)

_____
_____
_____

4.3 Describe THREE ways in which biotechnology can help people live better lives in a healthier world.

_____
_____
_____

QUESTION: 5

The statements in the table below are about biotechnology processes. For each statement, place a tick (√) in the space provided and give a reason for your choice.

STATEMENT	ACCEPTABLE	UNACCEPTABLE	REASON
1. Using genetically engineered micro-organisms to enable more efficient breaking down of human sewage.			
2. Changing the genes of plants so that they will grow better in salty soils.			
3. Altering the genes in an embryo* to treat a genetic disease.			
4. Adding genes to plants to increase their nutritional value.			
5. Altering the genes in fruit to improve their taste.			
6. Inserting genes from micro-organisms into crops to provide pesticide resistance.			
7. Inserting genes from plants into animals.			
8. Adding genes to yeast that is then used to make better tasting bread.			

*** Embryo – an organism in the early stage of development in the uterus (womb) of a female.**

Table adapted from Dawson, Vaille and Schibeci Renato (2003)

APPENDIX: 2 HISTORY OF THE DEVELOPMENT OF BIOTECHNOLOGY

Biotechnology in B.C	**500 BC:** The Chinese use mouldy curds as an antibiotic to treat boils •**250 BC:** The Greeks practice crop rotation to increase soil fertility •**100 BC**: Chinese use powdered chrysanthemum as an insecticide
Pre- 20Th Century Biotechnology	**1590:** Janssen invents the microscope •**1663:** Hooke discovers cells •**1675:** Leeuwenhoek discovers bacteria and protozoa •**1797:** Jenner inoculates a child with a viral vaccine to protect him from smallpox •**1802:** 1st time the term “biology” is used **1830:** Proteins, the building blocks of cells, are discovered •**1833:** The nucleus of the cell is discovered •**1855:** The E. coli bacterium is discovered •**1855:** Pasteur works with yeast, eventually proving they are living organisms •**1863:** Mendel discovers genes while working with peas. He lays the groundwork for genetics. **1879:** Fleming discovers chromatins •**1883:** The rabies vaccine is developed •**1888:** Waldyer discovers the chromosome
Biotechnology in the 1950’s and 1960’s	•**1953:** Watson and Crick understand the structure of DNA •**1954:** Cell-culturing techniques are first used •**1955:** An enzyme involved in the production of a nucleic acid is isolated •**1956:** The fermentation process is perfected •**1960:** Messenger RNA is discovered •**1961:** The genetic code is understood
Biotechnology in 1970’s	•**1972:** The DNA composition of humans is shown to be 99% similar to that of chimps and gorillas •**1977:** Genetically-engineered bacteria are used to make human growth protein •**1978:** North Carolina scientists, Hutchinson and Edgell, prove it is possible to introduce specific mutations at specific sites in a DNA molecule •**1979:** The first monoclonal antibodies are synthesized

APPENDIX: 2

HISTORY OF THE DEVELOPMENT OF BIOTECHNOLOGY……. continued

Biotechnology in 1980's	•**1983**: The first artificial chromosome is made •**1983**: The first genetic markers for specific inherited diseases are found •**1984**: The DNA fingerprinting technique is developed. •**1984**: The first genetically-engineered vaccine is developed. 1986: The first biotech-derived interferon drugs for the treatment of cancer are synthesized •**1988**: Congress funds the Human Genome Project •**1989**: Microorganisms are used to clean up the Exxon Valdez oil spill
Biotechnology in 1990's	•**1998:** Scientists clone three generations of mice from nuclei of adult ovarian cells •**1998:** Embryonic stem cells are used to regenerate tissue and create disorders that mimic diseases •**1998:** The Biotechnology Institute is founded by BIO as an independent, national, 501(c)(3) education organization •**1999:** The genetic code of the human chromosome is deciphered
2000 and Beyond	•**2000:** A rough draft of the human genome is completed •**2000:** Pigs are the next animal cloned by researchers to help produce organs for human transplant •**2001:** The sequence of the human genome is published in *Science and Nature* •**2002:** Scientists complete the sequence of the pathogen of rice, a fungus that ruins enough rice to feed 60 million people annually •**2003:** Dolly, the cloned sheep from 1997, is euthanized

Adapted from biotech.org

APPENDIX: 3 SUMMARY OF THE CONTENT FRAMEWORK FOR: LIFE SCIENCES, NATURAL SCIENCES, TECHNOLOGY AND CONSUMER STUDIES.

Biotechnology as per CAPS document for GET phase (Department of Basic Education, 2011a and b)

GRADE : 8	**TECHNOLOGY**
Impact of technology Processing	**The positive impact of technology:** many natural materials have been replaced in modern times by new or improved materials. Some new materials are environmentally friendly by being bio-degradable.
GRADE:9	**TECHNOLOGY**
Processing Indigenous technology	Preserving food (first two methods theoretically, 2.3 practically) 2.1. Storing grain 2.2. Pickling 2.3. Drying and/or salting

Biotechnology as per CAPS document for FET phase (Department of Basic Education, 2011)

GRADE :10	❑ Describe cancer as uncontrolled cell division and growth. ❑ Explain causes of cancer and treatment: traditional technology (traditional medicines and healers) and medical biotechnology (radiotherapy and chemotherapy – no details required). ❑ Research and present information on ONE type of cancer – causes, prevalence, treatment. Include beliefs and attitudes concerning cancer ❑ Investigate and collect information on one example of each of the following as it relates to plant and animal tissues: ▪ Stem cell research (current trends) ▪ Cloning ❑ Discuss ethics and legislation related to stem-cell research and cloning ❑ Describe the following as it relates to tissues: Traditional technology e.g. traditional medicines and healers Medical technology e.g. immunity, antibiotics, blood transfusion. List possible careers in biotechnology
GRADE : 11	Immunity: immune response of plants and animals against the infecting micro-organism; vaccinations (briefly) ❑ Use of drugs, e.g. antibiotics; effect on micro-organisms ❑ Use of micro-organisms to produce medicines (eg insulin, antibiotics) ❑ Traditional technology to produce eg beer, wine, cheese
GRADE :12	Genetic engineering: stem cell research, genetically modified organisms, biotechnology, cloning ❑ Mention of Mitochondrial DNA: tracing genetic links ❑ Paternity testing, DNA finger printing (forensics)

Biotechnology as per Hospitality Studies for FET phase (Department of Basic Education, 2003)

GRADE :10	HOSPITALITY /CONSUMER STUDIES
Food spoilage	• Micro-organisms -- Bacteria, moulds, yeasts and pathogenic micro-organisms. -- Factors influencing growth. -- Preventing the growth of micro-organisms: commercial and domestic. • Natural decay -- Enzymes, oxidation, natural toxicants
GRADE : 11	
Contamination	• Causes, prevention and control measures. • Microbiological contamination including high-risk foods and cross contamination, physical contamination, chemical contamination. • General symptoms of food poisoning – how to treat food poisoning.
GRADE: 12	
FOOD AND NUTRITION FOOD ADDITIVES	commercial and domestic use • What are food additives? Reasons for use, effect on food, safety and influence on health, possible allergic reactions. • Definition and explanation of the following food additives: -- nutrients, emulsifiers, stabilisers, bleach and colourants, chemical preservatives, anti-oxidants, additives to improve taste • Consumer issues regarding food additives, for example: do food additives enhance the nutritional value of foodstuffs such as energy drinks, chewing gum and potato chips? • Should these foodstuffs be available in school tuck shops?
FOOD LABELLING	• As a source of nutritional and other information for product selection. • Basic information that must appear on food labels • Interpretation of food labels. • Misleading nutrient content claims appearing on food labels.

GRADE : 12 FOOD RELATED CONSUMER STUDIES	**issues** impacting on the natural and economic environment, including public health • Genetically modified food. • Organically grown food. • Irradiated food. • Local food production and food security in South Africa. -- Self sufficiency, exports, imports -- Problems associated with local food supplies and possible remedies

APPENDIX: 4.1

PARENT INFORMATION SHEET

25 April 2013

Dear Parent

My name is Tanuja Sewsunker and I am a student in the School of Education at the University of the Witwatersrand.

I am doing research on grade 9 learners' knowledge of and attitudes towards biotechnology in two South African schools. This study is a case study.

My research involves your child answering a questionnaire which consists of two components i.e. a knowledge component which attempts to find out what existing knowledge grade 9 learners have about biotechnology. There is also an attitude component to identify the learners' attitudes about the use of biotechnology applications to enhance everyday life.

The reason why I have chosen your child's class is because the learners show a keen interest in finding out about biotechnology. I was wondering whether you would mind if your child participated in the project.

Your child will not be advantaged or disadvantaged in any way. S/he will be reassured that s/he can withdraw her/his permission at any time during this project without any penalty. There are no foreseeable risks in participating and your child will not be paid for this study.

Your child's name and identity will be kept confidential at all times and in all academic writing about the study. His/her individual privacy will be maintained in all published and written data resulting from the study.

All research data will be destroyed within 3-5 years after completion of the project.

Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,

Sewsunker

NAME : Tanuja Sewsunker

EMAIL : tanujasewsunker@yahoo.co.uk

TELEPHONE NUMBERS : 084 5140178 (C) 011 3150676 (W)

APPENDIX: 4.2

Consent Form for Parents: Questionnaire

Please fill in and return the reply slip below indicating your willingness to allow your child to fill in a questionnaire for my research project called:

Exploring grade 9 learners' knowledge of and attitudes towards biotechnology in two South African Schools: A Collective Case Study

Permission for the use of a questionnaire

I, _____ the parent of _____

Give/do not give my consent for my child to fill in a questionnaire.

Please place a tick (✓) within the brackets

[ ] I know that my child may withdraw from the study at any time and that s/he will not be advantaged or disadvantaged in any way.

[ ] I am aware that the researcher will keep all information confidential in all academic writing.

[ ] I am aware that my child's questionnaire will be destroyed within 3—5 years after completion of the project and that it will be kept safe until then.

[ ] I know that my child's identity will not be revealed.

Parent's Signature: _____ Date: _____

Contact person : _____

NAME : _____

ADDRESS : _____

TEL NUMBER : _____

APPENDIX: 4.3

25 April 2013

Dear Learner

My name is T. Sewsunker and I am a student in the School of Education at the University of the Witwatersrand.

I am doing research on grade 9 learners' knowledge of and attitudes towards biotechnology in two South African schools.

My investigation involves you answering a questionnaire which is made up of two parts. Section1 is based on finding out what ideas you have about biotechnology. Section 2 is to enable the researcher to identify what you think of the use of biotechnology processes such as genetic modification to improve and enhance our everyday life.

I was wondering whether you would mind answering the questionnaire and sharing your knowledge about biotechnology as this study is also an attempt to enhance what you learn at school.

Remember, this is not a test, it is not for marks and it is voluntary, which means that you don't have to do it. Also, if you decide halfway through that you prefer to stop, this is completely your choice and will not affect you negatively in any way.

I will not be using your own name but I will make one up so no one can identify you. All information about you will be kept confidential in all my writing about the study. Also, all collected information will be stored safely and destroyed within 3-5 years after I have completed my study.

If you are under 18 your parents have also been given an information sheet and consent form.

I look forward to working with you.

Please feel free to contact me if you have any questions.

Thank you

Yours sincerely

Sewsunker

NAME : T. Sewsunker

EMAIL : tanujasewsunker@yahoo.co.uk

TELEPHONE NUMBERS : 0731204254 (C) 011 3150676 (W)

APPENDIX: 4.4

UNIVERSITY OF WITWATERSRAND

FACULTY OF EDUCATION

Head of the Institute: Principal Midrand High School and Penelopele Oracle

Re: Request for permission to conduct research investigation at Midrand High School.

I am a Senior Life Science Educator and I am currently studying towards a Masters degree in Science Education through the University of Witwatersrand. I am writing this letter requesting consent / permission to conduct an investigation for my research project at your school.

The nature of my study intends to investigate the learner's knowledge of and attitudes towards the concept of Biotechnology. The group of learners which I wish involve in this study is the grade 9 Natural Science learners.

In order to proceed with this study it is necessary for me to administer questionnaires related to the topic on biotechnology. Once the questionnaires are completed, an analysis of the learner's response will be conducted.

All the information will be treated according to the universities ethical policy on confidentiality. I will not disclose the name of your institution unless you give me permission to do so.

1. The study is being conducted for educational purposes and will cause no harm to your learners.
2. Even if verbatim quotes from your learners are used in the research report, they will be reported so that their identity is anonymous. The results of the study may be published, but the learners' identities will be anonymous.
3. Everything that the learners say will be kept confidential by the researcher. The learners will only be identified by pseudonym in the transcript.

I would greatly appreciate your favourable response and I am happy to discuss my project with you if you so wish.

For any further clarification please do not hesitate to contact me.

Yours sincerely

Mrs T. Sewsunker

Senior Life Science Educator – Midrand High School Telephone: 011 – 315 0676 (OH)

Wits student no. : 584552 Email: tanujasewsunker@yahoo.co.uk

APPENDIX: 5

Wits School of Education

27 St Andrews Road, Parktown, Johannesburg, 2193 Private Bag 3, Wits 2050, South Africa
Tel: +27 11 717-3064 Fax: +27 11 717-3100 E-mail: enquiries@educ.wits.ac.za Website: www.wits.ac.za

Student Number:
584552

Protocol Number:
2012ECE183

Date: 23-Nov-2012

Dear Tanuja Sewsunker

Application for Ethics Clearance: Master of Science

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate has considered your application for ethics clearance for your proposal entitled:

Exploring grade 9 learners' knowledge of and attitudes towards biotechnology in two South African Schools: A Collective Case Study

The committee recently met and I am pleased to inform you that clearance was granted.

Please use the above protocol number in all correspondence to the relevant research parties (schools, parents, learners etc.) and include it in your research report or project on the title page.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely

MMabeta

Matsie Mabeta
Wits School of Education

011 717 3416

Cc supervisors: Ms. M Doidge & Mrs E Nyamupangedengu