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Cultivating the civic scientist: Science communication & tertiary biotechnology education

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Cultivating the Civic Scientist:
Science Communication & Tertiary Biotechnology Education

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Those who explore an unknown world are travelers without a map; the map is the result of the exploration. The position of their destination in not known to them, and the direct path that leads to it is not yet made.

- Hideki Yukawa, Japanese physicist
Cited in Robert Crease and Charles Mann,
The Second Creation, 1986

One thing I have learned in a long life: that all our science, measured against reality, is primitive and childlike – and yet it is the most precious thing we have.

- Albert Einstein

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

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ABSTRACT

Biotechnology is one of the most rapidly growing industries of the 21st Century and governments worldwide have invested significant funds to support research and development in this area. The belief that the commercialisation of biotechnology will offer significant social and economic benefits to the communities investing in this industry, however, is not a universally accepted view. Surveys of attitudes towards biotechnology in a number of countries have indicated that there are widespread concerns about the risks presented by the industry and the application of biotechnology products (Smith, 2001).

These public concerns have resulted in a stronger focus being placed on the mechanisms by which biotechnology is communicated with non-scientists (Gregory, 2003). In particular, improving the level of scientists' participation in public engagement has been afforded high priority (FASTS, 1999). Yet despite increasing calls for scientists to become more involved in this area, the perception that scientists are unwilling or unable to communicate persists (Stocklmayer, Gore, & Bryant, 2001). In response, the provision of quality science communication training for scientists and science students has been recommended (Royal Society, 2006b). This training should provide a fundamental support for improving scientists' ability to act as *civic scientists* by engaging with the public.

Using an Australian biotechnology degree program as a case study, this doctoral study examines how biotechnology education at the tertiary university level prepares science graduates for a civic science role. Qualitative and quantitative data were generated from 343 questionnaires and 36 interviews of key stakeholders in the chosen biotechnology program, including undergraduate and doctoral students, lecturers, postgraduate supervisors, and early-career biotechnologists recently graduated from the program. Additional interview data were also obtained from 10 science communicators and science communication lecturers.

The results of this study show that the current state of science communication training for the tertiary biotechnology students in the case needs to be improved. Few of the students felt their degree program provided them with any form of science communication training, let alone training in how to engage audiences broader than their peers. Many of the students were unaware of the communication skills training available to them, and few of the lecturers were able to identify where communication skills are taught within the program. While most of the interviewees supported the inclusion of science communication training within the biotechnology program, many of the lecturers were able to identify significant barriers to the provision of this training, including a perceived lack of interest in science communication training by the students. From the follow-up interviews with the students, it was evident that many do not value either communication with non-scientists or science communication training. On the whole, the stakeholders in the case were pessimistic about the likelihood of inclusion of science communication training within the science curriculum in the short term.

This study of a biotechnology program indicates that science communication training at the tertiary university level should aim to redress students' limited understanding of science communication and may need to be mandated through the inclusion of compulsory, assessed material in this area. Support for the delivery of science communication training, including the provision of accessible teaching materials, is required and a number of practical constraints for teaching science communication will need to be overcome. In particular, space will need to be made for this material in a curriculum that is already perceived to be overcrowded. Overall, science communication training should aim to generate scientists with scientist-to-scientist communication skills, the generic communication skills required by employers, and the civic science skills required for public engagement. But more fundamentally, science students and lecturers will need to appreciate the aims and significance of each of these areas of science communication.

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1. INTRODUCTION

1.1 Science and Society

In the present global knowledge economy, science is one of the most dynamic influences shaping society. Surveys of attitudes towards science indicate that society, as a whole, are supportive of science and appreciate its value for continuing economic prosperity and quality of life (Smith, 2001). However, public concerns about the rate of emergence of new technologies and the ability of governments to regulate these new developments have generated significant tension between science and society (House of Lords, 2000). This tension is predicted to increase as the pace of scientific development accelerates (AAAS, 2007).

The resolution of the tension between science and society is thought to lie with more comprehensive public engagement by scientists. Scientists have been charged with a duty to act as *civic scientists* by engaging the public in discussion and debate about the technical, and social and ethical aspects of research (Bodmer, 1985; House of Lords, 2000). While scientists acknowledge they should bear the main responsibility for communicating scientific research to the public (Wellcome Trust/MORI, 2000), they also acknowledge that their civic science role is often marginalised by competing time pressures and a lack of training and support in this area (Royal Society, 2006b). It has been suggested that a change in the culture of science is required whereby public engagement becomes an integral part of the scientific process itself, supported by formal acknowledgement of the importance of public engagement and the provision of time, training and reward for these activities (Wellcome Trust/MORI, 2000).

In recognition that science communication training for scientists and tertiary science students could be an integral means of promoting public engagement, a number of science communication training courses have been developed for scientists. Evidence suggests, however, that the uptake of these courses is not widespread amongst

scientists (Wellcome Trust/MORI, 2000). As tertiary science degree programs form the foundation of the science sector by providing a pipeline of university graduates entering into the profession, it has been proposed that formal science communication training be introduced at this early stage of career development (Royal Society, 2006b). This may enable science students entering into mainstream research areas to begin their careers as willing and able civic scientists.

While a number of universities in Australia and other countries offer science communication courses and programs, there has been no systematic analysis of science communication training for science students in Australia to date. It is not known how science education at the tertiary level prepares science graduates for a civic science role, what the stakeholders in tertiary science education think about the inclusion of science communication training in undergraduate and postgraduate science programs, and what these stakeholders expect the outcomes of this training to be.

1.2 Research Aims

This aim of this doctoral study is to examine how biotechnology education at the tertiary level prepares science graduates for a civic science role. Using a biotechnology program as a case study, the state of science communication training within this tertiary program is examined, the stakeholders' views of science communication and science communication training are described, and the factors that facilitate or inhibit the provision of this training are explored. Through the examination of science communication and science communication training within this case, a series of recommendations will be generated for the provision of best-practice science communication training within this biotechnology program. It is anticipated these evidence-based recommendations may be useful for other tertiary biotechnology programs that have yet to integrate science communication training into their science curriculum.

This case study centres on a biotechnology program because this field of science is seen as one of the emergent technologies of the century (NSF/DOC, 2002) and may serve as a useful model for other emerging technologies. In addition, biotechnology is a highly contentious and controversial area of science and there is a perceived need for biotechnologists who are capable of communicating the technical, social and ethical complexities of this discipline (Gregory, 2003). Thus the recommendations generated from this study may be useful for any field where technological controversy exists and public engagement needs to be improved. The specific biotechnology program selected for this case study was chosen because it was accessible to the researcher, but also because she had previously taught in the program and was familiar with the structure of the university offering the program, the program itself, and the staff teaching in the program.

1.3 Conceptual Framework

The conceptual framework underpinning this doctoral study was adapted from Godin and Gingras' (2000) *Multidimensional Model of Scientific and Technological Culture* which was developed to define scientific culture and how it can be measured. Godin and Gingras (2000) argue that historically, scientific culture has been represented as either one of two basic models (Figure 1). The first model presents science as a sphere that is independent, and often in opposition to, the sphere of culture (Model 1). The second model, which Godin and Gingras (2000) see as the most common model used today, separates science from culture but allows some links between the two (Model 2). These links are facilitated by diffusion from mediators such as science communicators.

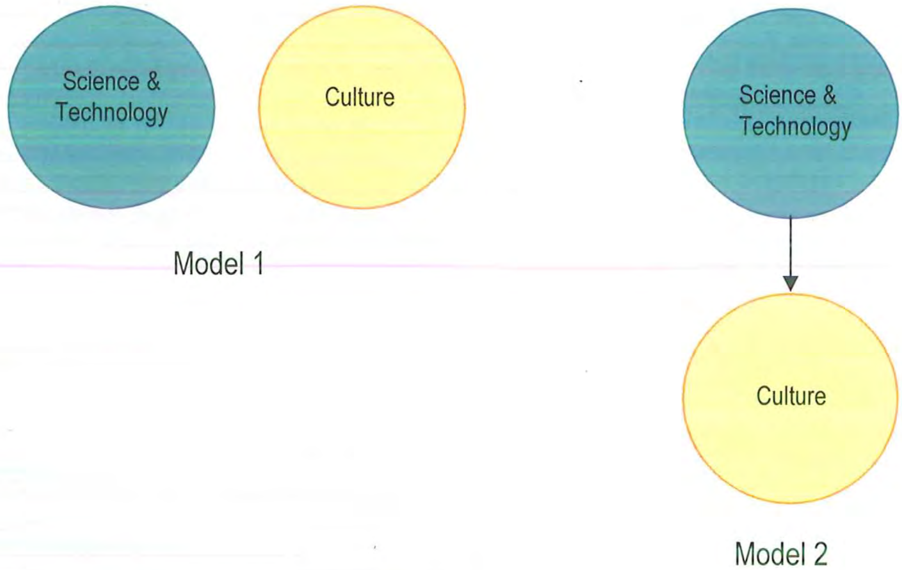

Figure 1: Two historical models of scientific culture (Godin & Gingras, 2000).

Godin and Gingras (2000) propose a third model of scientific culture that comprises a science and technology sphere sitting within a larger cultural sphere (Figure 2). They developed this model to improve the understanding of science and technology within culture, with the ultimate aim of improving indicators of scientific literacy. By repositioning science within culture, they feel that the individual and social dimensions of scientific literacy can be better appreciated and measured.

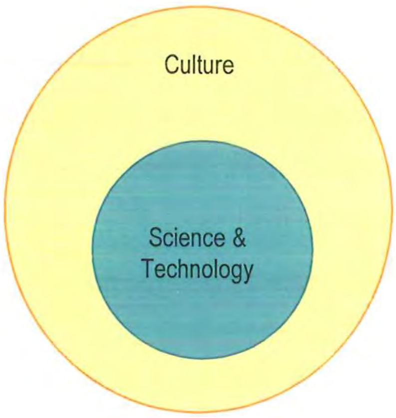

Figure 2: Godin and Gingras' (2000) *Multidimensional Model of Scientific and Technological Culture* (p. 53).

There is increasing recognition in the science communication literature of the importance of repositioning science within society. Haste (2005, p. 5), in the introductory comments of the British Association's review of science communication and public engagement, *Connecting Science*, suggests that scientific developments should be viewed from the "wider social context" where the sole responsibility for the development of science does not lie with scientists but where scientific issues are addressed by society as a whole. Major decisions concerning science in today's society are no longer made exclusively from within the sphere of the scientific community but increasingly in consultation with other social groups, such as politicians, bureaucrats, industry, non-government organisations, and the public (Greco, 2002). Communication between scientists and the broader society in this consultative process is seen by Greco (2002, p.1) to be "indispensable".

Positioning science and technology within the sphere of society, thereby placing science in context, is a fundamental tenet of constructivism. Pitrelli (2003) stresses the importance of acknowledging that social context plays a pivotal role in science today, and suggests that constructivist views of science communication have been neglected to the detriment of both science and society. Godin and Gingras' (2000) model of scientific culture is clearly in keeping with a constructivist view of science communication in which science is grounded within culture. A constructivist paradigm and framework underpins the present doctoral study.

The conceptual framework for the present doctoral study (Figure 3) is based on Godin and Gingras' (2000) *Multidimensional Model of Scientific and Technological* Culture. A number of minor alterations have been made to the model for the purpose of this study. The term *culture* has been replaced by the term *society* in keeping with the terminology more commonly used in the United Kingdom (UK) and Australia. As this case study is of a biotechnology program, the science and technology sphere has been replaced by a biotechnology sphere. (While the science and technology sphere is no longer explicitly represented in this framework model, this sphere still exists implicitly as a larger sphere in which the biotechnology sphere is located). Two additional components that are central to the present doctoral study – tertiary

education and science communication – have also been added to the model. These components are represented by two additional spheres that intersect with each other and the biotechnology sphere. The intersection of the biotechnology sphere and tertiary education sphere represents biotechnology training at the university level. The intersection of the biotechnology sphere and science communication sphere represents civic science. All three spheres sit within the sphere of society, indicating, as Godin and Gingras (2000) intended, that they constitute part of society.

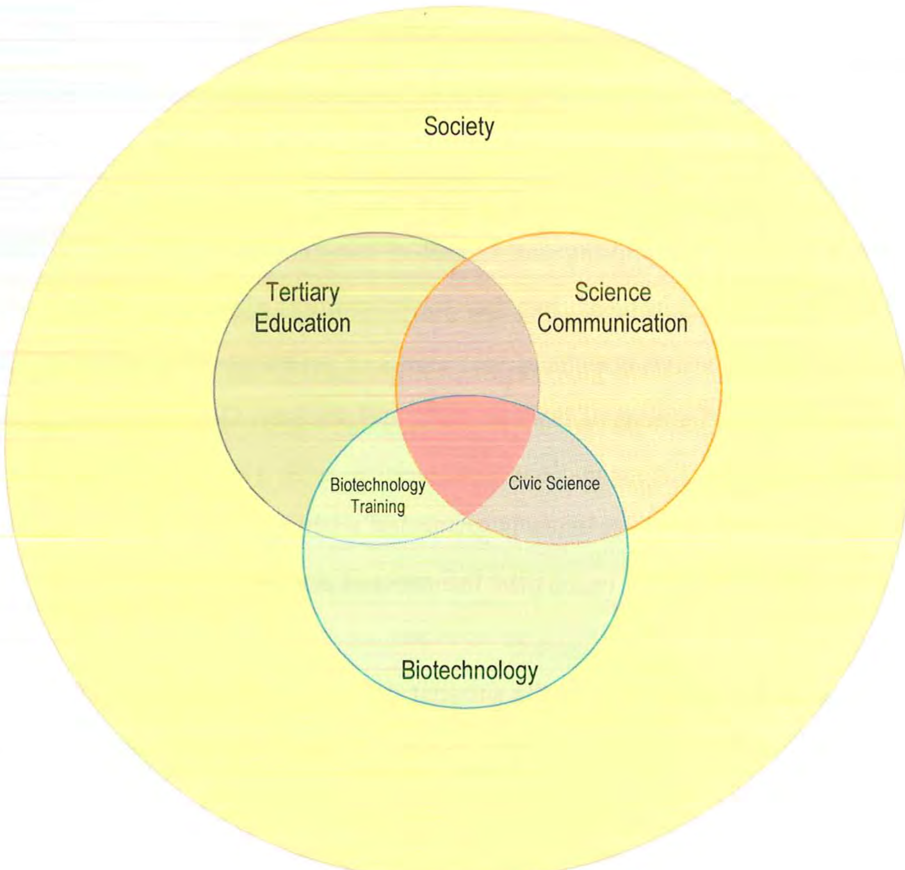

Figure 3: The conceptual framework underpinning the case study. Adapted from Godin and Gingras' (2000) *Multidimensional Model of Scientific and Technological Culture.* The intersection of the three spheres of the framework model -

biotechnology, tertiary education and science communication (highlighted in red) - represents the central focus of the present study.
The views of stakeholders from all three spheres represented in the framework are examined in this case study. From the biotechnology sphere the viewpoints of early-career biotechnologists are explored and from the science communication sphere the views of science communicators are examined. From the tertiary education sphere the views of students and lecturers are explored.

As some of the stakeholders interviewed in this case study can be positioned within two or more spheres of the conceptual framework, they provide views informed by knowledge of more than one sphere of the framework. These stakeholders include a number of lecturers with backgrounds in biotechnology research, and all of the early-career biotechnologists who are recent graduates of the biotechnology program. These lecturers and early-career biotechnologists represent both the tertiary and biotechnology spheres. Some of the science communicators interviewed also have biotechnology backgrounds, and therefore represent both the science communication and biotechnology sphere. In addition, all of the science communication lecturers interviewed had training in science communication as well as being tertiary educators, and two were also scientists prior to lecturing in science communication. Therefore, their contributions to this study come from a position informed from knowledge and experience of all three spheres represented in the conceptual framework.

While the aim of this project is to improve the science communication training and the civic science capacity of biotechnology students by exploring the intersection of the three spheres at the centre of this model, ultimately it is anticipated that this project may lead to the development of a new generation of civic scientists better prepared to constructively engage with the public and address the tension between science and society. By positioning all three spheres of the conceptual framework within the overarching sphere of society, this broad objective is also kept in focus.

1.4 Research Questions

The present study asks the stakeholders in the case study to draw on their knowledge of the spheres represented in the conceptual framework to examine the following research question:

How can biotechnology education at the tertiary level best prepare biotechnology graduates for a civic science role?

Three elements of this overarching question are examined more specifically in the case study. These elements are defined by the following research questions:

1. What is the current status of science communication education for tertiary biotechnology students in the case?
    a. What is the level of understanding of science communication amongst biotechnology students and what is their level of participation in science communication training?
    b. How well equipped do the doctoral students and early-career biotechnologists feel to undertake civic science?
    c. What is the lecturers' perception of science communication training in the degree program?
    d. What are science communicators' views of the science communication training that biotechnologists currently receive as part of their undergraduate and postgraduate degree programs?

2. How may the stakeholders' views of science communication impact on the provision of civic science training for undergraduate and postgraduate students in the biotechnology program?
    a. What are the stakeholders' views of the communication of biotechnology and biotechnologists' role in communicating with non-scientists?

b. How aware are biotechnologists of the approaches they can, and should, take to science communication?

3. What are the stakeholders' views of science communication training for undergraduate and postgraduate students in the biotechnology program?
    a. What level of importance do the students assign to science communication training?
    b. Is science communication training required and how should it be delivered?
    c. What are the barriers and supports for delivering science communication training within the biotechnology degree program?

The views of the stakeholders to these research questions, which represent all three spheres represented in the conceptual framework, will provide a rich description of the issue which lies at the intersection of these spheres – the civic science training of biotechnology students. By exploring and drawing together the views of these stakeholders to these research questions, it is anticipated this case study will usefully inform those involved in the development of science communication training for tertiary biotechnology students.

1.5 Overview of the Thesis

This thesis comprises eight chapters. The literature review is provided in Chapter Two. This review begins with a brief introduction to science in society and the proposition that science communication training for biotechnologists may provide one means of improving the relationship between biotechnology and society. The introduction is followed by an overview of biotechnology, science communication, the role of scientists in science communication, and their science communication training. The literature review concludes with consideration of science communication training for biotechnology students in the Australian context.

Chapter Three outlines the methods used in the study. It provides an overview of the constructivist paradigm that underpins the present research study, the rationale for the case study design and a description of each data gathering technique. The analysis of the quantitative and qualitative data obtained from these instruments is also outlined. The section concludes with how this research study has attempted to fulfil the constructivist criteria for quality of research design.

The results of the study are presented in Chapters Four to Six. Each of these chapters addresses one the three research questions previously indicated. Chapter Four addresses the current status of science communication education for tertiary biotechnology students in the case. Chapter Five examines the stakeholders' views of science communication impact on the provision of civic science training for undergraduate and doctoral students in the biotechnology program. Chapter Six explores the stakeholders' views of science communication and how they impact on the provision of civic science training for undergraduate and doctoral students in the case. The results presented in these chapters are derived from the quantitative data generated from the questionnaires delivered to the undergraduate biotechnology students and qualitative data generated from the interviews undertaken with individuals from all stakeholder groups in the study.

Chapters Seven and Eight provide the discussion and recommendations stemming from the results presented in Chapters Four to Six. Chapter Seven begins with a summary of these chapters then returns to the conceptual framework underpinning this thesis and discusses the results with respect to this framework. The implications of these results for the development of civic scientists through science communication training are explored by drawing together the data from each of the framework's spheres. The conceptual framework is then reconsidered and revised. Chapter Eight summarises the implications of these results and addresses how future research in this area may contribute to a better understanding of, and improvement in, science communication training. This chapter concludes with a series of recommendations for the best practice science communication training.

Combined with ongoing research in this area, it is hoped that improving the science communication training and the civic science capacity of tertiary biotechnology students, and ultimately tertiary science students in general, may lead to the development of a new generation of civic scientists better prepared to constructively engage with the public. This may place society in a better position to capitalise on the strengths of science and technology, and may place science in a better position to recognise the importance of public engagement.

2. LITERATURE REVIEW

2.1 Introduction

The present study examines the science communication education of tertiary biotechnology students, and focuses on the intersection between the spheres of biotechnology, science communication, and tertiary education. The following literature review provides an overview of each of these spheres. The review begins with a brief introduction to science in society and the proposition that science communication training for biotechnologists may provide means of improving the relationship between biotechnology and society. This is followed by an overview of biotechnology, science communication, the role of scientists in science communication, and their science communication training. The chapter concludes with consideration of science communication training for biotechnology students in the Australian context.

2.2 Science and Society

Science and technology are integral to modern life. With the proposed convergence of biotechnology with nanotechnology, cognitive science and information technology, science is predicted to have an even greater impact on the lives of future generations (NSF/DOC, 2002). Surveys of attitudes towards science indicate that the public, as a whole, are supportive of science and appreciate its value for continuing economic prosperity and quality of life (J. D. Miller, 2004). In contrast to the high levels of public interest in science, however, are public concerns about the rate of emergence of new technologies and the ability of governments to regulate these new developments (Hisschemoller & Midden, 1999; Quicke, 2001). Biotechnology, bovine spongiform encephalopathy (House of Lords, 2000), nuclear power (Hisschemoller & Midden, 1999), and environmental degradation (Quicke, 2001), in particular, have generated significant tension between science and society. This

tension is predicted to increase as the pace of scientific development accelerates (AAAS, 2007).

The UK's Select Committee on Science and Technology in the *Science and Society* Report (2000, p. 4) describe the current relationship that exists between science and society as a relationship "under strain". It is suggested in the report (House of Lords, 2000, p. 7) that:

> There has never been a time when the issues involving science were more exciting, the public more interested, or the opportunities more apparent. On the other hand, public confidence in scientific advice to Government has been rocked by a series of events, culminating in the BSE [bovine spongiform encephalopathy] fiasco; and many people are deeply uneasy about the huge opportunities presented by areas of science including biotechnology and information technology, which seem to be advancing far ahead of their awareness and assent. In turn, public unease, mistrust and occasional outright hostility are breeding a climate of deep anxiety among scientists themselves.

It was also noted in the *Science and Society* Report that public unease may not be resolved unless dialogue between scientists and the public is improved (House of Lords, 2000). Eckersley (2001) has also stated that resolution of the tension between science and society may not be achieved without a reshaping of science involving science communication. He suggests:

> Whilst remaining rigorous, science must become intellectually less arrogant, culturally better integrated and politically more influential. Science must become more tolerant of other forms of reality, other ways of seeing the world. It must become less remote from public culture, with a steadier and readier flow of influence between the two – in both directions. And it must contribute more to setting political agendas ....Science communication has a pivotal role in these changes. (p. 88)

In biotechnology, where rapid advances have generated considerable controversy and public concern, improved science communication training has been recommended as a fundamental support for improving scientists' ability to engage with the public (Clarke, 2001).

2.3. Biotechnology

Biotechnology is defined as "the use of living things in industry, technology, medicine or agriculture. Biotechnology is used in the production of foods and medicines, the removal of wastes and the creation of renewable energy sources (Biotechnology Australia, 2006). The term *biotechnology* was first used in 1917 by a Hungarian engineer called Karl Ereky. Ereky used this term to describe his integrated process for the large scale farming of pigs using sugar beet as a food source (Glick & Pasternak, 1998). From a historical perspective, however, the scientific discipline of biotechnology dates back thousands of years prior to Ereky's first use of the term. Traditional biotechnology began when yeast was first deliberately used to make bread and ferment beer and vinegar, and bacteria were first used to make yoghurt and cheese.

The discovery of the structure of deoxyribonucleic acid (DNA) and subsequent advances in DNA analysis and manipulation transformed biotechnology from a little known scientific discipline to an exciting and revolutionary discipline. Modern biotechnologists now have the tools to control how living cells and cellular components perform specific tasks. As a result, a significant number of new products and methodologies have been developed, including biotechnologies in healthcare, plant and animal agriculture, food production, and environmental technology. The powerful molecular technologies of biotechnology have moved the field to a position where is poised to revolutionise both science and global economics (FASTS, 1999). Biotechnology has been referred to as the science underpinning the third technological revolution - a revolution that is predicted to result in as significant a

change to everyday life as the preceding industrial and computer-based revolutions (Abelson, 1998).

Worldwide, the biotechnology industry is seen as a major area of investment and many governments are funding research and development to capitalise on the biotechnology revolution. In July 2000 the Australian Government launched the *National Biotechnology Strategy* (Biotechnology Australia, 2007). The key objective of this strategy is to support the nation's competitiveness in this field and provide a framework for the federal government and key stakeholders to work together to ensure that developments in biotechnology are captured for the benefit of the Australian community, industry and the environment, while safeguarding human health and ensuring environmental protection. To date, over A$117 million has been committed to this strategy (Biotechnology Australia, 2007). Additional Commonwealth funds have also been supplied to support Australian biotechnology programs in the health, agriculture, environment and education portfolios, as well as state and territory funded programs.

2.3.1 Public Perception of Biotechnology

While the Australian government and the governments of many other countries see the commercialisation of biotechnology to be of benefit for society and the economy, not all members of the public share this view. Surveys of the public's attitudes towards biotechnology in the United States of America (USA) and Europe indicate that biotechnology raises a number of issues for the public, including the *unnaturalness* of genetic manipulation, levels of acceptable risk and usefulness of new products (see Gaskell et al., 2000; Priest, 2000; Smith, 2001).

In Australia it is difficult to build a comprehensive picture of the public understanding and awareness of, and attitudes to, biotechnology. Europe uses the Eurobarometer (ec.europa.eu/public_opinion/standard_en.htm) to measure these qualities at a national level on a regular basis, and the Science and Engineering

Indicators (www.nsf.gov/statistics/pubseri.cfm?TopID=8&SubID=1&SeriID=2) are used for this purpose in the USA. Australia has no equivalent mechanism for collecting information of this nature. Biotechnology Australia, the federal government agency responsible for managing the *National Biotechnology Strategy* (in conjunction with its five federal government department partners), has examined Australian attitudes to biotechnology in a series of biannual surveys (Eureka Strategic Research, 2005; Millward Brown, 2001, 2003; Yann Campbell Hoare Wheeler, 1999). These surveys suggest the majority of Australians see the applications of gene technology as risky. In the 2003 survey (Millward Brown, 2003), the majority of Australians surveyed expressed at least some level of concern regarding the use of gene technology in general (80%), and specifically for human health applications (76%), and food and agriculture applications (79%). Most (56%) agreed that "only traditional breeding methods should be used to change hereditary characteristics of plants and animals" (p. 22).

In the most recent survey commissioned by Biotechnology Australia (Eureka Strategic Research, 2007), 1067 Australians between the ages of 18 and 75 years were surveyed to identify changes in community attitudes towards biotechnology. There was no measured improvement in knowledge of biotechnology from the survey from 2005 to 2007, and the majority (87%) expressed the view that gene technology was likely to create "significant problems in the future" (p. 13). While there were more positive perceptions of the future impact of biotechnology and increases in support for the use of gene technology in human health, medical applications, and food and agriculture, respectively, a large proportion of the participants still expressed concerns about the risks associated with the modification of plant genes to produce food and the use of gene technology in human transplants.

In using these relatively small surveys to assess community attitudes towards biotechnology, Biotechnology Australia have been criticised for treating the general public in an undifferentiated way. Dietrich and Schibeci (2003, p. 386) state "there is no such thing simple thing as an Australian public with monolithic views on gene technology". Analysis of attitudinal variation in the British public suggests the public

may be divided into a number of groups according to their views of science: confident believers, technophiles, supporters, concerned, not sure, and not for me (OST/Wellcome Trust, 2000). This scheme, however, has also been criticised for oversimplifying the complex relationship between the public and science (Gregory, 2003). Research into the public perception of science is now being conducted that acknowledges that the *public* consist of many *publics* who hold a diverse range of perspectives about science and technology. Future research in this area aims to explore the diversity of factors contributing to scientific attitudes, beliefs and understanding to provide a greater understanding of what underlies our current knowledge of acceptability of specific applications of biotechnology, how people use their values in decision-making, and how attitudes and values are managed (Weigold, 2001).

Until a better understanding of the underlying reasons behind the public perceptions of biotechnology are ascertained, negative public perceptions of biotechnology and the biotechnology industry are likely to continue to pose a number of significant problems for the industry. Community resistance to technological advances have resulted in the rejection of products outright and the inhibition of research and development progress through bans and moratoriums. This has been particularly evident in the genetically modified food industry in Europe, and increasingly in Australia (Smith, 2001). The peak professional body for the industry in Australia, AusBiotech, recently acknowledged that uncertainty about adoption of new biotechnologies by the community and regulatory bodies has prevented the Australian biotechnology sector from realising its full potential (Carroll, 2006). Stem cell and biodiscovery research, and genetically modified crops, in particular, are areas that have failed to translate from advances in research to economic and social advantage. A decreased ability to attract secondary students to undergraduate biotechnology programs in Australia has also been attributed to negative public perceptions of the industry. The skills shortage that is predicted to result from this reduction in undergraduate biotechnology enrolments has been described as "one of the biggest threats" to the biotechnology profession (Lavelle, 2006, p. 20).

Increased recognition of the influence of public opinion on biotechnology policy, venture capital support, research infrastructure, and the ability of the sector to attract students has led to a stronger focus being placed on communications about biotechnology with non-scientists. In 1999, the Federation of Australian Scientific and Technological Societies (FASTS) in their report *Biotechnology in Australia* (FASTS, 1999, p.2) stated:

> It is considered vital that widespread public consultation and informed public debate be undertaken as soon as possible, with mechanisms for ongoing communication. The most appropriate method of doing this is to bring together the stakeholders to identify and debate the key scientific, commercial, economic, health and safety, ethical, cultural and environmental issues....with an agreed education campaign to inform the general public as to the benefits of technology and the controls that are in place.

In the FASTS report (1999), the implicit intent of communicating with non-scientists was the increased acceptance of biotechnology products and processes. The broader biotechnology industry has also been accused of focusing public engagement activities on "modifying resistant anti-technology attitudes through education" (Hornig Priest, 2001, p. 97). It is now widely recognised, however, that the assumption that objections to biotechnology arise from a deficiency of scientific knowledge is misinformed, and increased public understanding of science does not necessarily equate to increased acceptance of new technologies (Whitmarsh & Kean, 2005). To the contrary, evidence suggests more educated segments of the population may be more critical of biotechnology (National Science Board, 2000).

One of the most important factors in predicting opposition to the biotechnology industry is thought to be a lack of trust in relevant biotechnology institutions, such as scientists, industry, government agencies and the media (Hornig Priest, 2001). It has been suggested that the way to guarantee the "generation and maintenance of public trust" (Hornig Priest, 2001, p. 108) in biotechnology is through the improved

engagement of biotechnologists with the public and acceptance of their public service obligation (Whitmarsh & Kean, 2005). Rather than attempt to fill a perceived deficit in understanding about biotechnology, biotechnologists should aim to build trust in their profession. They need to enter into discussion, dialogue and debate with the public about their research, show respect for public opinion, and accept public input into policy-making and scientific strategy. Clarke (2001,p. 51) suggests, "One of the major challenges ahead is to provide suitable opportunities for these exchanges to take place. The next step is to integrate these interactions (and their outcomes) into scientific policy". Clearly, this will require biotechnologists who appreciate the importance of science communication and are able to effectively engage with the public.

2.4 Science Communication

2.4.1 The Emergence of the Field of Science Communication

Since the Scientific Revolution, there have been many periods where scientists have been active in communicating science with the public. At the end of the 19th Century, however, when learned societies evolved into closed institutions, a gulf developed between the form of communication that occurs between scientists and the public the communication of science between fellow scientists (Gregory & Miller, 1998a). Today, the communication of science is even further divided. Not only does a gulf exist between public dialogue and dialogue between scientists, but specific disciplines within science have specialised to such an extent that scientists themselves find it difficult to communicate their research to scientists outside of their speciality and in addition, may be criticised for doing so by other scientists who see them as "saying too much" about issues outside their area of professional competence (Triese & Weigold, 2002, p. 314). Communication between scientists has become a "rigorously controlled system between professionals in their area of specialisation, often only after formal scientific publication in this area" (Junker & Trench, 2001).

As the communication of science has fluctuated over time, so too has the attitude of the scientific community toward engaging with the public. Whilst the 18^{th} and 19^{th} Centuries had periods of great advancement in public engagement, midway through the last century saw an unprecedented downturn in the public engagement with science in response to negative public perceptions of the cold war and nuclear power (S. Miller, 2001). By 1985, significant concerns about the decline in public support for science in the UK and scientists' lack of public engagement led the British Royal Society to commission a report entitled *The Public Understanding of Science* (1985). This report, commonly called the *Bodmer Report* after the chair of the working group Sir Walter Bodmer, aimed to review the public understanding of science, consider the constraints upon public engagement, and formulate how they might be overcome. The report concluded that scientists have a duty to communicate with the public and legitimised scientists' role in public engagement.

Since the release of the *Bodmer Report* (1985), interest in the popularisation of science has been reignited, particularly in the UK which is seen by some as at the "forefront in the promotion of the relations between science and society and in public scientific communication" (Greco, 2006, p. 1). The UK Government has commissioned a series of reports aimed at determining the current state of knowledge about the scientists and the publics' understanding, perceptions and attitudes in relation to science and science communication (COPUS, 1998; House of Lords, 2000; OST/Wellcome Trust, 2000; Royal Society, 2006a, 2006b; Wellcome Trust/MORI, 2000). It recently announced, as part of a ten-year investment strategy, the increased funding of its *Science in Society* program (Royal Society, 2007) from $10 million per annum to over $20 million per annum.

While the UK's *Science in Society* program (Royal Society, 2007) has developed to the point where it is seen by some as the leading science communication program in the world (Greco, 2006), the field of science communication has also developed significantly world-wide. Since the 1980s there has been a steady increase in practice and research aimed at promoting scientists engagement with the public. In many developed countries, national science communication programs have been

established by various government bodies and science institutions. The *American Association for the Advancement of Science (AAAS) Centre for Public Engagement with Science and Technology* was launched in 2000 to "boost public awareness and understanding of the nature of science and the work of scientists, while at the same time increasing public input into scientific research and policy agendas by creating a vehicle for real dialogue for policy makers, the general public and the scientific community" (AAAS, 2007). Other national science communication programs include Ireland's *Discover Science and Engineering Program* and South Africa's *Agency for Science and Technology Advancement* (see also Gascoigne & Metcalfe, 2001).

A significant advance in science communication worldwide has also been the development of a number of networks to disseminate science communication expertise (Clark & Illman, 2001). These networks include the *Public Communication of Science and Technology* (PCST) Network (www.pcstnetwork.org) and the *Science and Development Network* (SciDev.Net; www.scidev.net). The PCST network aims to promote public engagement and link researchers and scientific communities with the practitioners of PCST. SciDev.Net has similar aims but caters specifically for the developing world (Einsiedel, 2004).

In Australia, prior to 1994, science communication in this nation was described as an "isolated profession" in which there was "no organised way of talking to colleagues…no opportunity to share experiences or exchange ideas" (Metcalfe & Gascoigne, 2004). Since this time the profession has advanced significantly. Under the Backing Australia's Ability innovation statement (2004), the Australian Federal Government funded the *National Innovation Awareness Strategy* (NIAS) which aimed to increase the understanding of science and technology and appreciation of the commercial potential of innovation. With A$35 million in funding the NIAS program ran from 2001 to 2004. The federal government currently funds a *Public Awareness Program* that is managed by Biotechnology Australia (2006). This program has a number of elements including the monitoring of public awareness of biotechnology, provision of education materials and participation in community

forums. In 1994 the association for science communication professionals in Australia, Australian Science Communicators (ASC), was formed. Today, science communication in Australia is said to have greater recognition as a profession in its own right than in any other developed country (Metcalfe & Gascoigne, 2004).

2.4.2 Defining Science Communication

As a likely result of the rapid evolution of the science communication field and recent emergence of the science communication profession, there has been some confusion regarding the use of the term *science communication.* Science communication is most often described in terms of the activities of those involved, and as such very little insight is provided into the aims, scope or preferred outcome of science communication. For example, Triese and Weigold (2002, p. 311) define science communication as "the activities of professional communicators (journalists, public information officers, scientists themselves)". In a review of the science communication literature, Weigold (2001) avoids defining science communication altogether, which may reflect difficulty in pinpointing the exact definition of this term.

There has also been confusion about how the term science communication relates to the other closely related terms - *public understanding of science (PUS), scientific literacy,* and *scientific culture.* While all these terms have at some time been used interchangeably, none are synonymous, and they differ with respect to their underlying philosophy, approach and emphases (Burns, O'Connor, & Stocklmayer, 2003). In recognition that "the meaning of science communication and other terms used in the field of scientific literacy have been plagued by an unfortunate lack of clarity" (p. 183), Burns and coworkers (2003) published a paper that defined science communication and differentiates it from other closely related terms. In this paper, science communication progresses from being described as merely the collective activities of professional communicators, to being defined as a process with distinct

aims. These aims are defined as the collective aims of the public understanding of science, scientific literacy, and scientific culture movements.

2.4.2.1 Public Understanding of Science

The term *Public Understanding of Science* (PUS) was first coined in the *Bodmer Report (1985).* Defined as the understanding of scientific matters by non-experts, the PUS movement aims to improve the understanding and knowledge of scientific facts and scientific methods (Shapin, 1992). The term PUS, however, implies that any difficulties in the relationship between science and society are due to ignorance and misunderstanding by the public – difficulties that can be resolved by a one-way flow of scientific and technical information from scientists to the public. And while PUS activities aim to increase understanding by all non-experts, they have been found to attract only a narrow audience of individuals who are already committed to the philosophies of science (Turney, 1996). While communicating science with this audience may create an informed group of people, it is not inclusive and "unlikely to draw a wide range of people into debates about current science policy issues" (OST/Wellcome Trust, 2000, p. 12). In recognition of the need for public engagement that involves transparent and open dialogue between scientists and non-scientists, the PUS movement has now adopted the term *Public Engagement with Science and Technology* (PEST) to replace PUS (Science, 2002). In contrast to PUS, PEST aims to create a scientifically literate community through transparency, openness and dialogue (OST/Wellcome Trust, 2000).

2.4.2.2 Scientific Literacy

The scientific literacy movement aims to equip individuals with enough scientific knowledge to participate in a scientific and technological society. Derived from the concept of basic literacy – the minimum level of reading and writing skills that individuals require to function effectively in everyday life – scientific literacy has

been defined as the basic level of understanding of science and technology that individuals require to participate in the social, cultural and physical environments of society (Durant, 1992). According to Hornig Priest (2001), however, scientific literacy should include more than an understanding of the technical details of science. A basic level of scientific literacy should include:

> An understanding that boundary between science and policy is dynamic, that the impact of science is often uncertain, that policy reflects value-based decision making, and that the equitable distribution of risks and benefits associated with science and technology remain a substantial challenge. (p. 107)

This fuller vision of scientific literacy aims to equip individuals with an understanding and knowledge of three components of science and technology: the facts, the way in which scientific knowledge is generated, and the way in which decisions are made about what is science, and what isn't (Shapin, 1992). In light of this, Goodrum and coworkers (2001, p. 15) have redefined scientific literacy as "the capacity for persons to be interested in and understand the world around them, to engage in the discourses of and about science, to be sceptical and questioning of claims made by others about scientific matters, to be able to identify questions and draw evidence-based conclusions, and to make informed decisions about the environment and their own health and well being".

While universal high levels of scientific literacy are widely recognised as playing a critical role in advancing the wellbeing and prosperity of society, in practice however, they can be very difficult to achieve.

2.4.2.3 Scientific Culture

Scientific culture recognises that scientific literacy has a social dimension that is greater than the sum of the attributes and practices of individuals. In contrast to scientific literacy which focuses on the individual, scientific culture can be described as "an integrated societal value system that appreciates and promotes science and widespread scientific literacy as important pursuits" (Burns, O'Connor, & Stocklmayer, 2003, p. 189). Godin and Gingras (2000, p. 44) suggest that scientific culture is the "expression of all the modes through which individuals and society appropriate science and technology". They emphasise the social dimension of this culture, and suggest this dimension can be gauged by measuring the financial, regulatory, coordinating, education and communication activities of institutions, such as Government, teaching establishments, companies and funding agencies.

2.4.2.4 Science Communication

In bringing together the aims of PUS, scientific literacy and scientific culture, Burns and coworkers (2003) have produced a more comprehensive definition of science communication than previously cited in the science communication literature. They define science communication using a vowel analogy:

> The use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science....awareness, including familiarity with new aspects of science; enjoyment or other affective responses; interest, as evidenced by voluntary involvement with science or its communication; opinions, the forming, reforming or confirming of science-related attitudes; understanding of science, its content, processes, and social factors. (Burns, O'Connor, & Stocklmayer, 2003, p. 191)

2.4.3 Benefits of Science Communication

While the definition of the term science communication has been contested, the proposed benefits of science communication have been well documented. A number of utilitarian, democratic and cultural benefits have been proposed (Burns, O'Connor, & Stocklmayer, 2003). The utilitarian argument for science communication suggests that science communication can make science and technology more practically useful for individuals in everyday life. Whilst it is acknowledged that it is not necessary for individuals to know the technical intricacies of science and technology, it is however, deemed desirable for the public to be able to use the application of science and technology, and keep abreast of general developments in this area. Without sufficient knowledge of how science and technology is applied it may be difficult for people to make even the simplest of decisions, such as decisions about their diet, health and safety.

Science communication can also benefit the democratic process by providing citizens with sufficient information to enable them to "understand, think about, and perhaps participate in the formulation of public policy on specific issues" (Borchelt, 2001, p. 197). In a democratic society, people make decisions about scientific and technological policy matters when they vote, and an understanding of science can enable an individual to effectively contribute to this voting process. Broader discussion, debate and decision-making about issues that have a scientific component may also lead to greater public accountability about the direction and application of scientific research.

In addition to the proposed democratic and utilitarian benefits of science communication, it has been suggested that science communication can enhance social cohesion by facilitating the understanding, appreciation, celebration and sharing of science and technology. Science is part of our culture and heritage. As such, it should be shared by all and the specialisation and technicality of science should not be allowed to alienate the public (Gregory & Miller, 1998a). Aikenhead (2001, p. 23) believes that acknowledgement of the cultural nature of science may

reduce the possibility of miscommunication between the "scientific community engaged in research" and the "culture of a public immersed in their everyday lives".

In 2001, the *Research Roadmap Panel for Public Communication of Science and Technology in the 21st Century* summarised the benefits of science communication. This panel of US science communicators, communication researchers, journalists and scientists were brought together to provide a best practice model of science communication for the National Aeronautics and Space Administration (NASA). The panel found that agencies and institutions had three main purposes for communicating scientific information:

1. To inform consumers, patients and citizens about scientific activities, products, or conclusions that may be useful in improving the quality of life generally or in regard to specific problems, issues or events.
2. To provide information for citizens to enable them to understand, think about, and perhaps participate in the formulation of public policy on specific issues.
3. To provide descriptions and explanations of scientific work to enhance the level of scientific or biomedical literacy in the recipient.

2.4.4 Science Communication Models

Science communication, scientific literacy, scientific culture, PUS and PEST, are complex and multidimensional concepts. So too are the processes by which scientists and non-scientists communicate (Hartz & Chapell, 1997; Nelkin, 1995). As a consequence, models for science communication are complex. The science communication discipline has also been accused of unsound scholarship and evaluation, which further complicate the picture (Borchelt, 2001; Ziman, 2000) According to Borchelt (2001) science communication suffers from a:

> General lack of intellectual rigour applied to science and technology communication activities, especially as contrasted with the very rigorous scientific environment in which this communication arises. Communication often remains an afterthought, a by-product of scientific endeavour somehow removed from the scientific process itself. (p. 200)

Ziman (2000) criticises much of the current public communication practice for identifying and providing what the public ought to know, rather than identifying what the public wants to know and finding ways to make this knowledge available and accessible. This practice follows what is known as the *deficit model* of science communication (Borchelt, 2001).

The deficit model (also known as the deficiency, cognitive deficit, diffusion or persuasion model) aims to remedy deficiencies in technical understanding and increase public appreciation for science (Sturgis & Allum, 2004). This involves the transfer of scientific and technical information to a passive public, usually through formal education or the mass media. It is now widely acknowledged that the deficit model of science communication is not an effective means of achieving an increase in scientific literacy or public sympathy. The model has been criticised for its one-way, top-down communication approach that is often limited to the communication of scientific facts and methods (Gregory & Miller, 1998b) – a process Nelkin (1995) calls "selling science" and Prelli calls "propaganda" (Prelli, 2001, p. 77).

Sturgis and Allum (2004) however, do not advocate replacing this model entirely. They argue that potentially valuable theoretical insights and developments in science communication might be obtained by integrating the deficit model with the contextualist model – a combination that may give a more "complex and complete account of how what people know about science and the context in which it is practised affects the general favourability toward science and the scientific community" (p. 59). Despite these calls for integration, however, the deficit model has been largely abandoned for the contextual model of science communication (Ziman, 2000) . This model has significant support from science communication

scholars (as reviewed by Weigold, 2001) and is based on what Miller (2001) describes as the 3Ds – dialogue, discussion and debate.

> This approach sees the generation of new public knowledge about science much more as a dialogue in which, while scientists may have the scientific facts at their disposal, the members of the public concerned have local knowledge and an understanding of, and personal interest in, the problems to be solved." (S. Miller, 2001, p. 117).

The contextual model requires an understanding not only of the context of scientific knowledge, but how different people use this knowledge - a perspective which acknowledges the existence of other knowledge domains that influence understanding of, and attitudes towards, science and technology in opposite or conflicting ways to factual scientific knowledge (Sturgis & Allum, 2004). In the contextual model of science communication the public are viewed as specific groups of active and thoughtful citizens with expertise in the application of science and technology. According to Haste (2005), this model allows for the "open exchange and sharing of knowledge, ideas, values and beliefs between scientists, the public(s), stakeholders and decision-makers" (p.1) - it does not "remove authority or expertise from science; it locates scientific developments in a wider social context and enables the inclusion of a wider range of relevant expertise with regard to the application of such developments" (p. 5).

Godin and Gingras' (2000) *Multidimensional Model of Scientific and Technological Culture* illustrates this positioning of science and technology within culture. In this model, science is seen as a social phenomenon that "must necessarily be included as a form of the social organisation of culture" (p. 53). By positioning science within culture, Godin and Gingras (2000) suggest this model provides a better framework for the development of indicators of scientific literacy. They argue that the current indicators, which measure individuals' knowledge of science and their attitudes towards science and technology, are inadequate because they attempt to evaluate an individual's scientific literacy on the basis of the scientists' culture and do not take

their social roles into consideration. Using their revised model, in which the individual and social dimensions of scientific literacy can be better appreciated, Godin and Gingras propose a series of indicators that are more inclusive of these two dimensions.

Recently, France and Gilbert (2006) have attempted to develop a science communication model specifically for biotechnology. They contend that "no useful model for the processes of communication between the parties exists [the biotechnology community and the public community]" (p. 1). In the process of developing a model for communication about *modern biotechnology*, (which they define as the products and processes involving genetic modification) they have established five criteria that they feel a biotechnology communication model should address. These criteria are as follows (pp. 52-53):

1. The model should include all the major components that can be used to represent the shape of any attempt at communication. These are knowledge, nature of science and technology, affect, risk and language.
2. The model should be able to account for the effectiveness of current attempts at communication, as reflected in the state of public knowledge towards science and technology.
3. The model should suggest avenues of research that will lead to greater understanding of the processes involved and the issues arising from communications about biotechnology.
4. The model should predict approaches to communication that will lead to better mutual understanding between the stakeholders involved.
5. The model should be applicable both to the informal sector of voluntary, adult education and social action, as well as to schools where biotechnology education is provided.

While France and Gilbert (2006) represent the two groups of people involved in this communication model, the biotechnology community and the public, as separate spheres in the model, they recognise a shared space between the two communities

that can be used for discussion of problem solving. They conclude that the development of a model for dialogue between biotechnologists and the public is difficult, and their current model is incomplete. However, the development of such as model is crucial for the future of "the world, for the future of the biotechnology industry, and for the civic health of communities everywhere" (p. 54). A clearly defined model of science communication for biotechnology would also benefit those involved in the science communication training of biotechnologists.

2.4.5 Professional Science Communicators

As re-ignition of interest in public engagement has lead to the emergence of the science communication profession, careers in science communication have also evolved. To obtain a picture of who professional science communicators are, what they do and what influences their practice, Metcalfe and Gascoigne (2004) surveyed members of the professional body for science communication in Australia, ASC, via the organisation's email list. Of the 142 respondents, 77% called themselves science communicators consistently or sometimes. Of these, 20% reported science as their profession. The remainder were predominantly public relations, media or communications officers for a science-related organization (36%), freelance writers, consultants or journalists (46%). In contrast, others include science writers, journalists, TV and radio presenters, science centre and museum workers, and communication officers for scientific, environmental and industrial establishments as science communicators (Clark & Illman, 2001). Clearly there is some ambiguity in what defines a science communication professional, with some individuals calling themselves science communicators when their primary profession is science.

2.5 Civic Scientists

The former director of the National Science Foundation (NSF) in the US, Dr Neal Lane, originally coined the term *civic scientist* to describe the scientists who engage

with the public about science and society (Lane, 1997). More recently Clark and Illman (2001) expanded on the definition of a civic scientist: "A scientist who communicates with general audiences and brings knowledge and expertise into the public arena to increase awareness about science and/or facilitate discussion and decision-making on issues of importance to society" (p. 6). In the current study, the term *civic scientist* is used to distinguish between scientists and science communicators. The term is used to define scientists whose primary profession is science, but take on a communication role as required. Science communicators, in contrast, are defined in this study as professionals whose primary role is brokering communication about science.

2.5.1 Calls for Civic Scientists

The call for scientists to fulfil a civic science role has been in response to concerns about low levels of scientific literacy, dwindling enrolments in tertiary science courses, and decreasing public support and trust in science (Greenwood & Riordan, 2001; Lane, 1997; Neidhardt, 1993). It has been suggested that scientists should view science communication as a public service obligation (Borchelt, 2001) and should take more responsibility "to communicate about what they do, what they understand, what they still ignore, and most importantly, what gets them excited" (Delacorte, 2001, p. vii). Furthermore, the science communication activities they undertake should extend beyond a description of the technical aspects of their research (Gallagher, 2003):

> Scientists have become adept at converting the technical aspects of their work into lay terms, but that is not enough – societal and ethical implications must be acknowledged….the scientific community needs to position the socially revolutionary aspects of research onto centre stage. This is the case in high school teaching, but it fades at the undergraduate level and scientists rarely integrate these aspects into actual research projects.

Scientists have been accused of abrogating their responsibility to communicate (Chaisson & Kim, 1999) and warned that they ignore public attitudes and values at their peril and the peril of the scientific research community (Bodmer, 1985; Greenwood & Riordan, 2001). A study commissioned by the Wellcome Trust (Wellcome Trust/MORI, 2000) found that 56% of 1540 UK scientists surveyed reported participating in communication activities. In a more recent web-based survey of 1485 research scientists in higher education institutes in the UK, 74% reported having taken part in at least one science communication activity in the past twelve months (Royal Society, 2006b) While this suggests a high level of involvement of scientists in science communication activities, closer inspection of these surveys indicates the opposite may be true. As Greco (2006) observes, the most frequent activity reported in the 2007 survey was participation in an institutional open day event - an event that is likely to be compulsory for most scientists. Over 70% of the scientists surveyed had not been interviewed by print or radio journalists, had not taken part in a public debate about science, and had not worked with science centres, museums, teachers or students. Greco (2006, p. 1) suggests the scientific community is "trapped in its splendid isolation" and "uncomfortable in its timid relations with society".

2.5.2 Barriers to Civic Science

A significant number of barriers have been identified as reasons for the perceived low level of involvement of scientists in science communication programs and activities. The Wellcome Trust survey of UK scientists (Wellcome Trust/MORI, 2000) indicated the majority (60%) of scientists feel the day-to-day requirements of their job leave them with little time to communicate. Most felt the need to spend more time on research was the major barrier to participation in science communication. One fifth of the scientists agreed that scientists who engage with the public are less well regarded by other scientists, and 3% cited negative peer pressure as a barrier to involvement in public engagement. In a similar poll in the USA (C. P. Brown, Propst, & Woolley, 2004), 74% of scientists in the international honour

society of scientists and engineers, Sigma Xi, agreed they had little time for public outreach activities. In addition, 41% indicated that their involvement in science communication activities or programs is "futile" (p. 300) as it makes no difference to public policy. Other studies have indicated additional barriers to civic science including a lack of faith in the media, and lack of training, support, money and incentives (Shortland & Gregory, 1991).

Aikenhead (2001) suggests a number of barriers to civic science stem from the culture of science itself. Scientists working within this culture are guided by the norms, values and expectations of science which affect their capacity to act as civic scientists, often in a negative way. These include the increasing specialisation and technical complexity of science, the vast growth in the volume of scientific knowledge, and the culture of distrust of journalists and broadcast media (Triese & Weigold, 2002). Goodell (1977) also believes the scientific community exercises a powerful system of control over its members, which dictate a series of rules for civic science. The rules include popularising only when the productive phase of a research careers is over, sticking strictly to a specific area of expertise, acting only to improve the public image of science, avoiding extremes of opinion, establishing a reputation as a credible researcher before communicating with the public, and publishing in the technical literature before presenting this research to the public. Despite the recent suggestion that there has been a cultural change in the attitude of scientists such that civic science activities are no longer seen "beneath the dignity" of a researcher, (House of Lords, 2000) other research indicates that "going public" is still considered by fellow scientists to be neglectful of serious scientific research (Royal Society, 2006b; Weigold, 2001)

The increasing specialisation and technical complexity of science also presents a number of major hurdles to effective science communication by scientists. Science has become increasingly inaccessible to non-scientists, particularly in the areas that involve mechanisms that are counter-intuitive (Boulter, 1999). Furthermore, the language of the scientific culture has "diverged from the mainstream of literary language and divided into a large number of small winding tributaries" to the extent

that it is now largely incomprehensible to non-scientists (Shortland & Gregory, 1991, p. 12). In order for scientists to be effective science communicators, they must be skilled at translating ideas (including counter-intuitive ones) from the technical language of their discipline into a form that is accessible to lay audiences.

The vast growth in the volume of scientific knowledge also presents a series of barriers to effective science communication. Scientists are experts in their own area of specialisation, but may not be familiar with other fields of knowledge, and may therefore find it difficult to communicate how their field integrates into the *big picture* of science. As Weigold (2001, p. 179) states:

> Scientists are specialists, involved in the minutia of a specific problem that may represent a small piece of a much bigger puzzle. This can make it difficult for them to state why their most recent discovery is a newsworthy event or even a significant development. Scientists offer predictions that are tentative and qualified, which may seem incompatible with fostering excitement in a story.

However, this information may be important for the public who require an understanding of science for everyday life. Civic scientists must be comfortable with communicating the ways in which their particular field of expertise fits with other fields of knowledge, including the counter-culture notion of providing a big picture of their given field.

Peer review is another process embedded in the culture of science that presents another barrier to science communication by scientists. This peer review process is the system science uses to assess the quality of research before it is published and involves scientific experts in the field check papers for validity, significance and originality and clarity (Sense About Science, 2004). By withholding information from the public until a level of peer consensus is achieved, the peer review process is said to protect the public from premature release of information that might prove misleading. Given that 71% of the public look to scientists to have an agreed view

about science issues (Science Media Centre/MORI, 2002), this process is supported by those who feel it offers the public protection from the "sometimes messy process of science" (Roan, 2001, p. 11). The *Journal of the American Medical Association* (JAMA) include in their instructions to authors a warning about public discussion of their work (including speaking to reporters or participating in press conferences) prior to publication in the journal (Fontanarosa, Flanagin, & DeAngelis, 2000). However, the very act of *protection* afforded by peer review, insulates non-scientists from understanding the way in which science is conducted and how consensus is achieved. As noted by the USA's National Academy of Science :

> Science results in knowledge that is often presented as being fixed and universal. Yet scientific knowledge obviously emerges from a process that is intensely human, a process indelibly shaped by human virtues, values and limitations, and by societal contexts (1995, p. 9).

The culture of distrust of journalists and broadcast media in science also provides a barrier to effective science communication. The conflicting goals, values and routines of scientists and journalists have been well documented (as reviewed by Weigold, 2001). Scientists have accused journalists of trivialising, distorting and misrepresenting science. Journalists have similarly levelled criticisms at scientists, seeing them as "narrowly focused, obscure and self-absorbed" (p. 179). In part, these criticisms stem from the divergent agendas of the two professions.

> The scientist's primary responsibilities are to disseminate information, educate the public, be scientifically accurate, not to lose face before colleagues, get some public credit for years of research, repay the taxpayers who supported the research, and break out of the ivory tower for the sheer fun of it. The journalist's goals are to get the news, inform, entertain, not lose face before his or her colleagues, fill space or time, and not be repetitive. (p. 181).

At a more basic level, science communication may be difficult for scientists because they may not understand either what science communication is, or what it involves. There is evidence to suggest that some scientists cannot distinguish the broader science communication practice required of a civic scientist with the communications about science they share exclusively with their peers (Weigold, 2001). These two very distinct roles, termed *public science* and *private science* by Holten (1978), have different social settings and different audiences. Aikenhead (2001) suggests that no matter how entwined that popular and the technical might appear to disinterested observers, the two forms of communication, and the two communities they reach, are very distinct. As such, very different modes of communication are required.

2.5.3 Civic Science in Practice

While many of the barriers to science communication outlined above may be reduced by the use of an intermediary science communication professional, evidence suggests scientists still believe they should bear the main responsibility for communicating scientific research to the public. The Wellcome Trust poll, *The Role of Scientists in Public Debate*, found that 84% of the UK scientists surveyed agreed they have a duty to communicate to the non-specialist public (Wellcome Trust/MORI, 2000). It has been suggested, however, that scientists do not fulfil this role particularly well. In the introduction to *Science Communication in Theory and Practice*, Stocklmayer (2001, pp. xi-xii) presents anecdotal evidence to support this claim:

> The imperative (to explain their work to the general public) generates both anger and anxiety among scientists when confronted by it....The idea that science is culturally dependent, that knowledge is constructed, threaten their mastery of their discipline. They feel uncomfortable, unhappy and yearn for the certainties and security of their laboratories and their white coats....It (science communication) threatens both their standing with their colleagues and their self-respect.

The view that scientists are not effective communicators appears to be shared by a large majority of the public. An opinion poll of public attitudes to science, engineering and technology commissioned by the UK's Office of Science and Technology (Science Media Centre/MORI, 2002) found that 85% of the public surveyed indicated that scientists needed to improve the way they communicate their findings through the media. Scientists themselves have also expressed the view that scientists are poor communicators. Hartz and Chappell (1997, p. 38) observe:

> With the exception of a few people...we (scientists) don't know how to communicate with the public. We don't understand our audience well enough – we have not taken the time to put ourselves in the shoes of a neighbour, the brother-in-law, the person who handles our investments – to understand why it's difficult for them to hear us speak. We don't know the language and we haven't practised it enough.

Other surveys of scientists provide a broader picture of the views held by scientists about their science communication capacity. The Wellcome Trust poll of 1540 UK scientists found that the majority fairly well equipped to communicate the scientific facts (57%) and the social and ethical implications (52%) of their research (Wellcome Trust/MORI, 2000). A similar survey in the USA, however, found that only a small majority of the scientists polled (51%) were aware of how they could become involved in public outreach activities (C. P. Brown, Propst, & Woolley, 2004). Neither of these studies however asked the respondents to rate how effective they feel they are at science communication, they did not assess the science communication ability of these scientists, nor did they rate the effectiveness of their activity or activities. Therefore, while these studies indicate a willingness to communicate on behalf of scientists, it does not offer any evidence that willingness to communicate equates to good practice.

To overcome the lack of involvement in science communication by scientists, it has been suggested that science communication become a core component of scientists' job descriptions (Borchelt, 2001). While not all support a mandated civic science role

for all scientists (Clarke, 2001; Royal Society, 2006b), it has been suggested that a change in current practice is required whereby science communication is not seen as an optional part of a research program, but as an integral part of the scientific process itself (House of Lords, 2000). This should be supported by formal acknowledgement of the importance of science communication by the top levels of management in institutions and research funding bodies. In addition, time should be set aside for communication, positive civic scientist role models should be promoted at all levels, and there should be reward and remuneration for civic science activities. Science communication training for scientists should also be provided. Haste (2005, p. 15) suggests:

> In general it seems that scientists are supportive of greater dialogue but their main concerns are lack of competence to communicate and the lack of recognition or reward for this activity, compared to research itself. The perceived barriers are skill, not attitude, as well as lack of validation of the activity by employers and peers... If scientists are the main source [of communication], then communication skills training is needed.

2.6 Communication Training for Scientists

In response to the suggestion that science communication training for scientists and tertiary science students will be an integral means of promoting civic science, a number of funding and training opportunities have been made available for scientists to improve their involvement in public engagement activities. In many countries communication skills and media training resources, including courses and grants are offered which aim to equip scientists with the skills to communicate their science with the public and with the media. Evidence suggests, however, that the uptake of science communication courses and programs is not widespread amongst scientists. In the UK's *Factors Affecting Science Communication* survey (Royal Society, 2006b), 73% of the scientists surveyed indicated they had not undertaken any media, communications or public engagement training. Clearly a more systematic approach

to science communication training is required if this training is expected to produce a generation of scientists able and willing to engage with the public.

Recently, there has been increased recognition of the role that science communication training can play at the undergraduate and postgraduate level (Clarke, 2001; House of Lords, 2000; Royal Society, 2006a). As science degree programs form the foundation of the science sector by providing a pipeline of graduates entering into the profession, it has been proposed that formal science communication training be introduced at this early stage of career development. The provision of training at this level is also likely to stimulate involvement of researchers in public engagement at an early stage of their career. The Royal Society has recommended that "policies are developed which enable a higher proportion of younger scientists to get involved with public engagement" (Royal Society, 2006b, p. 6).

How science communication training at the undergraduate and postgraduate level might be practically achieved has yet to be determined. Recently, a review of public engagement training at this level was recommended by the UK's Royal Society (Royal Society, 2006b). Earlier, the *Science and Society* report (House of Lords, 2000) concluded that research and teaching institutions should strongly encourage communication training for students, in particular media training, and recommended that "strenuous efforts be made by universities to see that as many students as possible take full advantage of this opportunity" (p. 4). As the bulk of science communication programs focus on communication through television and print media (Boulter, 1999), media training for science students is clearly warranted. However, there is increasing recognition that other forms of communication, and therefore other forms of science communication training, have an important role to play in science communication:

> There is no such thing as a one-size-fits-all public communication message for a mythical lay public....An individual article or story placed in an individual news medium is more likely to be lost in the very crowded

> market place than it is to have a profound impact on public understanding of science....The effectiveness of communication – the accurate receipt and use of information – can be improved substantially by carefully defining intended audiences and by tailoring the level of information provided to each audience (Boulter, 1999, p. 202).

The delivery of media skills training in isolation has also been criticised for its inability to reconcile the different approaches of scientists and journalists. Haste (2005) suggests that scientists and journalists can only be reconciled if the underlying philosophical differences between the professions are addressed. In addition to media training skills, science communication training should aim to include instruction about the place of science in society and culture to improve scientists' awareness of their changing status and of the need to respond to the public's demand for more openness. Until science communication training is broadened to address all of these issues, scientists' communication with a wider audience will not be significantly improved (Boulter, 1999).

2.6.1 Tertiary Science Communication Training in the Australian Context

The importance of communication training for science students has recently been highlighted in Australia with the release of two reports assessing the relationship between the curriculum content in science degrees and employer and industry needs: *What Did You Do With Your Science Degree* (ACDS, 2001) commissioned by the Australian Council for the Deans of Sciences (ACDS), and Macquarie University's *Science, Engineering and Technology* (SET) study (Macquarie University, 2006). Both investigated graduates' and employers' perceptions of the skills provided by undergraduate science degrees.

The ACDS report (2001) was commissioned to obtain a picture of employment patterns for science graduates in Australia and the skills provided to these graduates in first decade of their careers. One of the specific aims of the study was to identify

employer perceptions of the skills attained by science students during the course of their studies, and the extent to which those skills are valued by these employers. The report surveyed 1245 students who had completed a degree in science in the period of 1990-2000 from six different universities selected to represent Australian universities as a whole. Representatives from 16 enterprises and recruitment agencies were also surveyed for their views on these issues.

The *What Did You Do With Your Science Degree* report (ACDS, 2001) found that employers required graduates with the ability to communicate. Whereas in the past, science graduates were not necessarily required to have skills other than technical skills, the report found that employers now seek people with the ability to translate scientific terms and ideas into language that can be understood by a diverse range of people (such as engineers, management, clients, researchers, and the public). Almost 90% of the 1245 graduates surveyed, however, stated that their degree training did not provide them with the level of communication skills required by their employer. They also indicated that they felt these skills were not often taught in science degrees. A high level of oral communication skills, in particular, was identified by nine out of ten of the graduates as a requirement for their current employment. Only four out of ten indicated they gained such skills in their undergraduate degree program.

Macquarie University's SET Study (Macquarie University, 2006) also surveyed science graduates and employers. This study was commissioned to examine why science careers are not pursued by school leavers in Australia resulting in a decline in enrolments in the science, engineering and technology areas over time and particularly in recent years. Over 300 Macquarie University students and 70 professional scientists were surveyed. The study found that employers do not believe a basic tertiary science education equips graduates with the essential generic skills required, particularly effective written and oral communication skills. Cribb (2006, p. 32) when reviewing this study suggested that "Those who believe that a qualification in science enables a person to communicate effectively are mistaken. A science degree doesn't make you a sympathetic listener, good at dialogue or a clear writer.

Indeed, it sometimes appears to have the opposite effect". The majority of recommendations arising from the SET study (Macquarie University, 2006) centered on increased science communication; between universities and industry and government bodies, universities and high schools, as well as universities and the community at large.

The ACDS (2001) and SET reports (Macquarie University, 2006) assessed the skills requirements of science graduates in general. In contrast, a recent review of Australian biotechnology programs was undertaken to assess the skill requirement of biotechnology graduates in particular. Commissioned by the Australian Universities Teaching Committee (AUTC) the aim of this report was to gauge if these programs meet the needs of the Australian biotechnology industry. The resulting report, the *Review of Biotechnology* (Gray & Franco, 2003), provided an evaluation of biotechnology programs offered by 25 Australian universities. As with the ACDS and SET reports, it also concluded that there is a strong industry demand for graduates with communication skills. The report indicated that while generic communication skills are taught in the majority of biotechnology degrees (predominantly in the first and second years of study) these skills were taught "with varying degrees of efficacy" and recommended the "identification and dissemination of best practice" for teaching oral and written communication skills (p. 4).

While all three of these Australian reports highlight a need for improved generic communication skills training of science graduates, these studies did not assess the specific science communication skills required of civic scientists. The employers in the ACDS study (2001), indicated that they felt graduates required the communication skills for public engagement, however, these skills were not described. In the SET study (Macquarie University, 2006) communication skills were not defined. And in the AUTC report (Gray & Franco, 2003), the communication skills described were a generic set of communication skills, including written communication skills (memoranda, email, letters, lab reports and posters) and oral communication skills (presentations, face to face communication, professional consultation and negotiation). The extent and nature of science

communication education provided to the biotechnology students in the programs surveyed was not explored and there was no reference in the report to the communication skills required for public engagement.

What is required is science communication training offered within science programs that provide students with civic science skills, in addition to the generic communication skills required by employers and the specific skills required for scientist-to-scientist communication in traditional research areas. While science communication education is offered by many universities, including many Australian universities that offer biotechnology programs (including the ANU, the University of Queensland, the University of New South Wales, the University of Technology Sydney, the University of South Australia and the University of Western Australia) it is recognised that these science communication programs may attract students who will seek employment within the science communication industry and may not reach science students who enter the workforce in mainstream research areas (Errington, Bryant, & Gore, 2001). Scientists' capacity for public engagement is unlikely to be improved unless science communication training reaches science graduates who pursue careers in mainstream science.

To date, there has been no systematic analysis of science communication training for science students in Australia. The extent and nature of science communication training for science students is unknown. How science communication training should be delivered to science students and what the achievable outcomes should be, are also unknown. It is important to establish therefore, what stakeholders in science education think about the inclusion of science communication training into undergraduate studies and what their expectations are of such a program. This may help shape the design of such programs, how well received such courses are, and how successful they are both in the short term and long term in generating science graduates who enter into mainstream research as willing and capable civic scientists.

This doctoral study examines how a tertiary biotechnology program prepares science graduates for a civic science role. By exploring the views of students, lecturers and

other stakeholders, this study aims to provide recommendations for curriculum planners for the provision of science communication training within biotechnology programs. It is hoped these recommendations will usefully inform those involved in the development of science communication training for tertiary biotechnology students which will ultimately lead to a new generation of biotechnology graduates able to constructively engage the public in discussion about their science.

3. METHODS

Educational procedures, practice and contexts are investigated from various theoretical perspectives. These theoretical perspectives, also known as paradigms, provide the foundation that determines what research is and how it is to be practised. The following methods section provides an overview of the constructivist paradigm that underpins the present research study. The rationale for the case study design and each data gathering technique is also described and the corresponding instruments are provided in the appendices. The analysis of the quantitative and qualitative data obtained from these instruments is also outlined. The section concludes with how this research study has attempted to fulfil the constructivist criteria for quality of research design.

3.1 Paradigms in Educational Research

First coined by Thomas Kuhn (1970) as the central concept in his theories of scientific progress in the physical sciences, the term *paradigm*, has been adopted by the social sciences to describe "a basic set of beliefs that guides action" (Guba, 1990, p. 17). While the physical sciences remain a single paradigm science (with broad consensus on a particular paradigm within the scientific community), the social sciences are seen as multiple paradigm sciences with a number of paradigms competing for dominance (Masterman, 1970). These paradigms are characterised by their approach to ontological, epistemological and methodological questions: What is the nature of *reality*? What is the relationship between the researcher and the known? How should the researcher go about finding out knowledge?

3.1.2 Paradigm Dialogue

Each research paradigm in the social sciences has its own research practices and methodological assumptions. There has been significant debate about what which of

these paradigms represents the *correct* paradigm, how research is *best* practised, and which method is the *most appropriate* to use. Gage (1989) describes this debate as the "paradigm wars" (p. 1). However, as paradigms cannot be proven or disproven in any foundational sense, there are no independent criteria that can be used to judge which paradigm is most appropriate for research.

In educational research, the *paradigm wars* have centred on positivism versus constructivism. The positivist approach argues that the social world is like the world of natural phenomena, that is, hard, real and external to the individual (Cohen, Manion, & Morrison, 2001). The constructivist approach is diametrically opposed to this position, arguing instead that reality is interpreted and constructed by individuals based on their experience and interaction with the environment. Many believe the divide between these paradigms cannot be combined in any one research project as each one rests on an incompatible set of theoretical assumptions about the nature of social science (Lincoln & Guba, 1985). Guba (1993, p. x) states "the naturalistic (constructivist) paradigm is incommensurable with positivism in the same way that the notions of flat earth and round earth are conceptually incommensurable".

Berg (2001, p. 3) however, likens restricting the research design to either constructivism or positivism to "opening a tool box, choosing a spanner and ignoring the other tools available". Many, like Berg, believe the paradigms used in educational research can and should be accommodated (Firestone, 1990, p. 1). These *compatibilists* feel there is a sound epistemological foundation to uniting the different disciplinary perspectives and their methods of research (Keeves, 1997, p. 1):

> These two approaches are not different in purpose in so far as they seek to build a coherent body of knowledge....They supplement each other in the methods employed and the contributions they provide....Research activity has a unity of purpose and a unified epistemological basis that demands the rejection of two or more paradigms of research.

Proponents of multi-method research, who deliberately combine different types of methods within the same investigation, also believe that two or more paradigms may be accommodated within educational research. Furthermore, they believe the integration of different theoretical perspectives that can result from this accommodation can be used to promote the generation of conceptual linkages between the opposing theoretical systems (Brewer & Hunter, 1989). Guba (1990) argues, however, that the debate about which paradigm should dominate is irrelevant as none of the paradigms is the paradigm of choice. He believes that the current multiple paradigm state that exists in educational research (and the social sciences in general) should be replaced with a new paradigm, in a process similar to the paradigm shifts that occur in the physical sciences:

> Each is an alternative that deserves, on its own merits...to be considered. The dialog is not to determine which paradigm is, finally, to win out. Rather, it is to take us to another level at which all of these paradigms will be replaced by another paradigm whose outlines we can see now but dimly, if at all. That new paradigm will not be a closer approximation to the truth; it will simply be more informed and sophisticated than those we are now entertaining. (Guba, 1990, p. 27)

For the time being however, until this more informed and sophisticated paradigm is developed, "fitness for purpose" has been suggested as the guiding principle that educational researchers should adopt when approaching their research (Cohen, Manion, & Morrison, 2001, p. 37). Rather than advocating adherence to a single paradigm, this approach takes the view that different paradigms are suitable for different research purposes and should be adopted accordingly. The justification for the choice of instrumentation and data collection should therefore be outlined clearly in a methodology that has a foundation in the ontological and epistemological assumptions of the paradigm or paradigms of choice.

3.2 Methods

The research design and methods of the present study were developed within a constructivist paradigm (Lincoln & Guba, 1985). This paradigm was chosen on the basis of its fit with educational and science communication research. In teaching and learning, recognition of prior knowledge, peers, learning experiences, and social interactions is important (Tobin & Tippens, 1993). In science communication, the contribution of social context and "local knowledge" to the use of science by the public has also been recently acknowledged (Pitrelli, 2003). It is anticipated that by taking a constructivist approach to the present study, an in-depth understanding of the awareness and views of science communication and science communication education will be generated that will provide a foundation for educational reform in this area.

3.2.1 Case Studies

Case studies are the method of choice for constructivist research because of their emphasis on interpretation and subjective observation. Yin (2003, p. 13) defines a case study as "empirical research that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". According to Stake (2000) case studies involve the systematic gathering of holistic information about the case and analysis of the case's issues, contexts and interpretation. They arise from a need to understand complex social phenomena and provide a "rich and vivid description" of events (Hitchcock & Hughes, 1995, p. 317). It is the unique design of the case study, rather than the data collection approach, that distinguishes case studies from other approaches to research.

Several types of case study have been described. Stake (2000) defines three types of case study based on the underlying purpose for studying the case. The *intrinsic* case study provides an understanding of a particular case, because of either its uniqueness

or ordinariness. The *instrumental* case study is undertaken to assist the researcher to understand some external theoretical question or problem, rather than the case per se. And the *collective* case study involves an extension of an instrumental case study to several cases in order to better understand or theorise about a larger collection of cases. All three types involve an analysis of the case's issues, contexts and interpretations and all ask "What can be learned here that a researcher needs to know?" (Stake, 2000, p. 440).

3.2.2 Case Study Data Analysis

The content analysis of the qualitative data generated from a case study offers an opportunity to learn about how the subjects of the research view their social worlds (Berg, 2001). The qualitative data is reduced and transformed to make it accessible and systematically comparable. From the transcripts generated from interviews and other data collection methods, trends and patterns are identified and transformed into categorical themes. The data is then coded according to these categories, and patterns, commonalities, relationships or disparities are identified. The results are displayed as an organised, compressed assembly of information that permits conclusions to be drawn. This form of content analysis offers the researcher an ability to learn about how the subjects of the research view their social worlds (Berg, 2001).

The categories researchers use in content analysis of qualitative case study data can be determined deductively, inductively, or by a combination of both (Strauss, 1987). Researchers using a deductive approach analyse the data in light of categories suggested by a theoretical perspective. In the inductive approach, researchers identify themes as they emerge during the process of data analysis: a process which allows them to *ground* these categories to the data from which they derive (Berg, 2001). To present the most forthright presentation of the constructed realities of the subjects, a greater reliance on induction is required. However, in many circumstances both inductive and deductive approaches are used.

Underpinning both inductive and deductive approaches to content analysis is experience that derives from analysis of the literature or previous research (Berg, 2001). Insights and general questions about the research derived from these experiences play a role in the development of inductive categories. In deductive reasoning, these experiences are used to create the various deductions required to drive the analysis. The interplay of experience, deduction and induction form the basis of the formation of theory, known as *grounded theory* (Glaser & Strauss, 1967, pp. 2-3):

> To generate theory...we suggest as the best approach an initial, systematic discovery of the theory from the data of social research. Then one can be relatively sure that the theory will fit the work. And since categories are discovered by examination of the data, laymen involved in the area to which the theory applies will usually be able to understand it, while sociologists who work in other areas will recognise an understandable theory linked with the data of a given area.

The grounded theory developed from such analyses should be verified and assessed using negative case testing (Denzin, 1978). This process involves identifying all examples of cases that do not fit the proposed hypothesis (the negative cases) and either discarding or reformulating the hypothesis to account for, or exclude, these cases. The data is then reanalysed in light of these changes.

3.2.3 Case Study Design Quality

Valid research in all fields must demonstrate its truth value, provide the basis for applying it, and allow external judgements to be made about the consistency of its procedures and the neutrality of its findings or observations (Erlandson, Harris, Skipper, & Allen, 1993). While methodological soundness should be measurable

regardless of the chosen paradigm, these questions of goodness and value need to be explored in relation to the paradigm in which they operate. A major strength of the case study is the ability to use many different sources of evidence for data collection and the subsequent ability of the researcher to build data triangulation into the research design (Yin, 2003). Triangulation is defined as the use of multiple methods of data collection for the study of some aspect of human behaviour (Cohen, Manion, & Morrison, 2001). By combining different kinds of data, researchers can refine, broaden, and strengthen conceptual linkages (Berg, 2001)

Triangulation, however, is only one way in which constructivist research demonstrates its methodological trustworthiness. Constructivist researchers also apply other measures of goodness and value, including measures of credibility, dependability, confirmability, and transferability (Guba & Lincoln, 1981; Guba & Lincoln, 1989; Lincoln & Guba, 1985). Measures of credibility reflect the subject's degree of confidence in the truth of the findings. The subjects of the research are supplied with the researchers' interpretation of their realities, allowing them to judge the degree of compatibility of the constructed realities that exist in their minds with those that are attributed to them by the researcher. This process is known as member checking. Lincoln and Guba (1985) also recommend that credibility can be improved by prolonging the engagement of the researcher in the context to be studied, maintaining persistent observation of the case, collecting reference materials to provide a more holistic view of the context (known as referential adequacy materials), and encouraging peers to provide feedback on the case report that may allow redefinition of the research.

For constructivists, variance in results upon retesting may not indicate error but a shift in the construction of reality from one point in time to another. In place of reliability, constructivists measure dependability using an audit trail. By providing documentation and an account of the process of the research, an external audit can be made on the processes by which the study was conducted. This dependability audit will check the stability of the instruments used and the traceability of explainable changes (such as changes in reality of subjects or better insights by the researcher).

This audit process can also provide an external check on the *confirmability* of the study. This measure recognises that objectivity is an illusion and that no method can be insulated from the bias of an observer. Hence, the conclusions, interpretations, and recommendations of the researcher are checked in a confirmability audit to determine if they are supported by the research, rather than if they are free from contamination by the researcher.

Constructivists also believe the definition of research problems cannot be fully determined prior to commencement of a study, as they are partly found in the constructed realities of the stakeholders. Subsequently, the research problem, questions and working hypotheses or recommendations should initially be stated in terms that are sufficient to guide data collection, then refined and expanded as the study proceeds. This interactive process of data collection, data analysis and design review, is known as emergent design (Erlandson, Harris, Skipper, & Allen, 1993). The refining process of emergent design is interactive because it involves the sharing of constructed realities with the stakeholders. The design emerges from the researcher's understanding of these realities and the context.

In addition, constructivists believe that regardless of their surface similarities, social settings are made up of different complex individuals related in a multitude of undefined ways. Consequently, a case report cannot be generalised, as no two social settings are sufficiently similar to allow generalisation from one to another. In place of generalisability, constructivists speak of transferability – the extent to which the findings can be applied in other contexts or to other respondents (Berg, 2001). The detailed description of the case and purposive sampling methods used, enable the reader to determine if the study can provide insights for their own use. The reader may learn through the vicarious experience they gain by reading the case report (Stake, 2000).

The aim of the present study is to generate a case report that is transferable at the very least to other biotechnology programs, and potentially transferable to any other program involving the delivery of material linked to an emerging science discipline

which may or may not involve technological controversy. This study centres on a biotechnology program because this field of science is seen as one of *the* emergent technologies of the century and thus it may serve as a useful model for other emergent technologies. In addition, biotechnology is a highly contentious and controversial area of science and there is a perceived need for biotechnologists who are capable of communicating the technical, social and ethical complexities of the discipline (Gregory, 2003). Thus the recommendations generated from this study may be useful for any field where technological controversy exists and public engagement needs to be improved.

3.3 Biotechnology Program Case Study

The present research study centres on an instrumental case study. This case design was chosen because, while the purpose of the study is to develop the issues, contexts and interpretations of tertiary science communication education in the particular tertiary biotechnology case chosen, ultimately the aim of the study is to generate a case report with recommendations that are transferable to other tertiary biotechnology programs. Therefore it was important to select a program where aspects of the program were reasonably typical of other biotechnology degrees.

The case chosen for analysis in the present study is a biotechnology degree program offered by an Australian university. The units offered in its program are representative of the combination of science and non-science content areas that characterise Australian biotechnology programs according to the description provided in the AUTC's Review of Biotechnology (Gray & Franco, 2003, p. 16). According to this review the science content of these biotechnology programs typically consist of molecular biology, cell biology, immunology, microbiology, biochemistry, and physiology. These programs also include the manipulation and culture of bacterial, plant and mammalian cells and other specific biotechnology skills linked to the plant, animal, environmental, medical, and industrial areas of biotechnology. Non-scientific content is also incorporated in these programs,

including knowledge of intellectual property protection and patenting, a basic understanding of the main principles of business planning and commercialisation of a product, and ethical debate and communication.

Another reason for selection of the particular biotechnology program chosen for the case study was accessibility and familiarity. As a previous employee of the university within the chosen degree program, the author of the present study has intimate knowledge of the program through teaching many units in the program, and is known to many of the stakeholders. This familiarity with the interviewees and the case facilitated easy access to, and cooperation from, the "gate-keepers" of the study (Erlandson, Harris, Skipper, & Allen, 1993, p. 56), namely the lecturers of the undergraduate biotechnology students and the supervisors of the postgraduate students. These gate-keepers not only represented an important group to interview in their own right, but also provided the key to accessing the undergraduate and postgraduate students.

In the chosen biotechnology program, the undergraduate Bachelor of Biotechnology degree can be completed in three years and the Honours degree in four. There is an average of 57 students enrolled in the undergraduate biotechnology degree program over the three years of the program. A number of additional years may be required for completion if the degree is combined with other degrees, other major or minor programs, and/or part-time enrolment. Students receive training in animal, plant, microbial enzyme and food biotechnology. The degree program is described as follows in the 2007 University handbook:

> The [biotechnology] major provides broad training as well as in-depth study in selected areas so as to generate graduates capable of operating in an interdisciplinary environment. Consequently the major provides the opportunity to gain experience in the biological, chemical and commercial aspects of biotechnology with an emphasis on the development of the skills and knowledge applicable to a wide range of biotechnological processes. Areas studied include genetic engineering, immunology and vaccine

production, fermentation technology and cell culture. Specialisation may be incorporated into the degree through the appropriate choice of double majors and minors. All students in the Biotechnology major are encouraged to obtain on the job training in industry, which may be achieved via an Industry Practicum or through a Professional Placement.

A number of elective units are available to the undergraduate students enrolled in the biotechnology program, including cross-disciplinary units offered by other divisions of the university. One of these cross-disciplinary elective units is a unit in science communication. The unit aims to provide students with an understanding of science communication, the dominant models of science communication, and the contexts in which science communication occurs. It also analyses the mediation role of professional science communicators (including science journalists) between scientists and the general community. In the unit outline it is stated that by the end of the units students should be able to:

1. Understand and be sensitive to major issues facing science communicators;
2. Understand the major procedures which can be brought to bear on these science communication issues;
3. Analyse critically science communication output and science communication research; and,
4. Apply knowledge and interest in a special area of interest in science communication.

This unit is offered from within the arts division rather than the science division and is not formally promoted as a recommended unit in any of the science programs.

In addition to this unit in science communication, the university also provides communication skills training to all undergraduate students. This skills training is part of the university's graduate attribute training program. This program aims to

ensure all students of the university graduate with a number of generic attributes, one of which is communication. This attribute is defined by the university as the "ability to communicate effectively and appropriately in a range of contexts using communication, literacy, numeracy and information technology skills". Delivery of materials designed to teach the generic attributes are embedded within the learning objectives, activities and assessment of the core units of all programs of study.

The biotechnology program in this case study also offers postgraduate studies in biotechnology. As these students are enrolled in postgraduate studies in the combined biological science and biotechnology postgraduate program it is not possible to determine what number of students are engaged specifically in biotechnology projects. On average 60 full-time students are enrolled in this program. The postgraduate program is described by the university as providing students with:

> The opportunity to undertake research degree within an extremely active research and postgraduate training environment. The program has a particularly fine reputation for providing the opportunity for students to undertake their research on biological issues of importance to [the state]....The program has established a number of long-term links with industry and with government agencies to augment the high standard of research training available. International links have also been established across all of the major themes of biological research training offered by the program.

The postgraduate students enrolled in the biological science and biotechnology program are not offered any specific training in science communication, but informal training in this area may be provided by supervisors. While the university's policy outlining the responsibilities of the supervisors of postgraduate research students does not stipulate the provision of communication training, it does state that supervisors should discuss supplementary training with their students, including the generic skills program that is available to all postgraduate students in the university.

The *Responsibilities of the Postgraduate Research Student Supervisors* policy states that at the beginning of the research project the supervisor is responsible for "arranging any orientation or supplementary training necessary for the research project, including the Generic Skills Program." This generic skills program incorporates a module on communication skills training. The module is taught by the teaching and learning centre and is promoted to all postgraduate students in the university via their email and the distribution of a hard-copy promotional flyer. The skills program courses do not cater specifically for science students.

3.4 Data Generation Methods

3.4.1 Sample

Five groups of key stakeholders were identified in the case: undergraduate biotechnology students, doctoral biotechnology students, early-career biotechnologists, biotechnology lecturers and the supervisors of biotechnology postgraduate students. In this study early-career biotechnologists are defined as researchers within their first five years of biotechnology related employment following completion of undergraduate or postgraduate research. All of the early-career biotechnologists interviewed in the present case study had completed their undergraduate degree in the biotechnology program that is the focus of this case study.

Additional contextual data to supplement the case study was obtained from interviews of lecturers of tertiary science communication units and science communicators in the biotechnology field, and undergraduate students enrolled in related science degree programs at the same university. These related science degree programs include biology, biomedical science, molecular biology, conservation biology, environmental biology, marine biology, chemistry, and veterinary science.

Table 1 summarises the method used to collect data from each of the five stakeholder groups, and the number of individuals in each group administered a questionnaire or interviewed. The lecturers and postgraduate student supervisors were combined into one group as all of the individuals who lectured in the undergraduate biotechnology program were also supervising students undertaking doctoral studies in biotechnology.

Table 1

Summary of the Data Collection Method used for each Stakeholder Group

	Stakeholder group	n	Data collection method
Case Biotechnology program	Undergraduate biotechnology students	69	Questionnaire
		13	Interview
	Doctoral biotechnology students	7	Interview
	Early-career biotechnologists (graduated <5 years from the biotechnology program)	6	Interview
	Lecturers and postgraduate research supervisors in biotechnology program	10	Interview
Additional Contextual Data	Undergraduate science students	274	Questionnaire
	Science communication lecturers	3	Interview
	Biotechnology science communicators	7	Interview

3.4.1 Ethical Considerations

University ethics approval for the study was obtained prior to commencement of data collection. All attempts have been made to honestly portray each individual's viewpoints expressed in the questionnaires and interviews while simultaneously protecting their privacy. The questionnaires were anonymous and the interview required the participants to identify themselves by their first name only. To keep these individual's responses confidential, each individual's first name was replaced with a pseudonym, and the name of the institution linked to the case study has not been divulged. It is acknowledged, however, that unavoidably, some readers on the basis of contextual data and the responses provided by participants may be able to identify the university involved and possibly identify individual participants.

Prior to participating in the study, stakeholders were provided with an information letter that informed them of the nature and scope of the research study. (See Appendix 1 for an example of the information letters provided to the undergraduate students and interviewees). The letter supplied to the undergraduate students indicated that those who filled in the questionnaire were presumed to have consented to participation in the study. The interviewees were asked to sign a consent form prior to participation in the study. (See Appendix 2 for the interview informed consent form). All stakeholders were informed of their right to refuse to take part in the study, their right to withdraw from the study at any stage, and confidentiality arrangements regarding analysis, dissemination and publication of research findings. Participants in the interviews were also provided with an interview schedule at least two days prior to their interview (See Appendix 3 for an example of an interview schedules provided to interviewees). It was stated explicitly in the introduction to the interview schedules that the questions provided were only indicative of the type of questions that may be asked and during the course of the actual interview additional questions may be asked.

3.4.2 Undergraduate Questionnaires and Follow-Up Interviews

3.4.2.1 Instrument Design

As questionnaires are easy to administer to large numbers of subjects and the undergraduate students were the largest of the stakeholder groups, a self-administered questionnaire delivered in a lecture timeslot was chosen as the most appropriate data collection for the undergraduate students. Access to the students was negotiated with each lecturer responsible for coordinating the individual units in which data was collected.

Two questionnaires were designed for administration to the undergraduate students. The first questionnaire was administered to biotechnology students in the lecture timeslot of a second year unit in animal biotechnology. This questionnaire (see Appendix 4) was designed to address aspects of all three research questions. To explore Research Question 1 (What is the current status of science communication education for tertiary biotechnology students in the case?) the undergraduates were asked to define science communication, indicate how aware they are of the science communication training available to them, and describe their views of the science communication training they receive. To explore Research Question 2 (How may the stakeholders' views of science communication impact on the provision of civic science training for undergraduate and postgraduate students in the biotechnology program?) the students were asked for their views on public engagement and science communication. To explore Research Question 3 (What are the stakeholders' views of science communication training for undergraduate and postgraduate students in the biotechnology program?) the students were asked to rate the importance of science communication training.

The questionnaire comprised 50 items arranged into 16 questions. Three of the items were open-ended and four required a dichotomous response to questions about degree program enrolment, sex, and age. The remaining 43 items, which asked questions specifically about their science communication and science communication

training, required the students to mark their responses on a continuous rating scale. Many of these rating scale questions were adapted from interview questions asked in the UK survey *The Role of Scientists in Public Debate* (Wellcome Trust/MORI, 2000). The focus of these questions, the wording of these questions, and the corresponding question asked in the student questionnaire in this study are listed in Table 2.

A second, shortened version of this questionnaire (hereafter referred to as the shortened questionnaire) was administered to students attending lectures for first and third year biotechnology units in introductory chemistry and molecular biology, respectively. The first year unit is a compulsory unit for students in the science division of the university, and consequently has a significant number of students attending. The logistics of distributing and collecting a large number of questionnaires within a short period dictated that the questionnaire administered to the students attending this lecture needed to be significantly shorter than the questionnaire administered to the second year students. The third year students were also administered the shortened questionnaire as the lecturer of this unit was unable to grant any longer than a 15 minute period at the end of a lecture for data collection.

The shortened questionnaire addressed the third research question only (What are the stakeholders' views of science communication training for undergraduate and postgraduate students in the biotechnology program?) The students were supplied with one rating scale question which asked the students to rate the importance of 12 curriculum items in their undergraduate program. The questionnaire also contained the four dichotomous questions about degree program enrolment, sex, and age, and whether the students were aware of, and planned to enrol in, the science communication unit.

Table 2

Questions Adapted For Use in the Undergraduate Student Questionnaire from the survey The Role of Scientists in Public Debate (Wellcome Trust/MORI, 2000).

Focus of question	Wellcome Trust Survey Questions (Wellcome Trust/MORI, 2000)	Corresponding Question in Undergraduate Questionnaire
Perceived importance of public engagement.	Q29 To what extent do you agree or disagree that the non-specialist public needs to know about the social and ethical implications of scientific research?	How important do you think it is that the non-scientists understand (a) the technical aspects of biotechnology research (b) the social and ethical implications of biotechnology research?
Who should scientists communicate with?	Q3 If you had to communicate your research and its social and ethical implications, who do you think would be the most important group to communicate with?	How would you rate the importance of communicating (a) the technical aspects of biotechnology research with the following groups? (b) the social and ethical implications of biotechnology research with the following groups?
Who is responsible for communicating science with the public?	Q11a: How strongly do you agree or disagree with the following statement? Scientists have a duty to communicate their research and its implications to the non-specialist public.	How responsible should the following groups be for communicating (a) the technical aspects of biotechnology research with non-scientists? (b) the social and ethical implications of biotechnology research with non-scientists?
	Q30 In your opinion, who, if any, of the following should have the main responsibility for communicating the social and ethical implications of scientific research to the non-specialist public?	
Impact of peer review on public engagement.	Q11h: How strongly do you agree or disagree with the following statement? Scientists should publish findings only when they are peer –reviewed.	How strongly do you agree or disagree with the following statements? Biotechnologists have a responsibility to communicate (a) the technical aspects of their research with non-scientists (b) the social and ethical implications of their research with non-scientists (c) their research and its implications with non-scientists, but only after peer review.

3.4.2.2 Rating Scale Items

Both the questionnaire and the shortened questionnaire contained rating scale items, also known as visual analogue or graphics scale items (Oppenheim, 2001). Each scale was drawn as a 10cm horizontal line on the page immediately below each item in a question, and was bounded by a pair of labels that varied according to the question (unimportant – very important, strongly disagree – strongly agree, not responsible – very responsible; Figure 4). The respondents were instructed to "Indicate your response by marking a cross on the line".

How important do you think it is that the non-scientists understand...
Indicate your answer by marking a cross on the line.
Place a cross in the box next to the question if you don't know the answer.

...the technical aspects of biotechnology research?

Unimportant ●————————————————● *Very important*   *Don't know* ☐

Figure 4: Example of a rating scale item used in the undergraduate biotechnology student questionnaires. (Note: The rating scale in this figure and in the appendices has not been reproduced to scale. In the questionnaire administered to the undergraduate students, the rating scale line was exactly 10cm in length).

Graphic rating scales have been widely used in the literature (Friedman & Amoo, 1999) primarily because they are quick and easy to answer and quantify, but also because they do not restrict responses to discrete categories. The rating scale response format chosen in the present study was selected for these reasons but also because it represented an alternate response format to Likert scales. The students in the present case study are very familiar with Likert-type scales as a result of their constant exposure to teaching feedback surveys, and as a consequence may be at risk of providing responses without giving adequate thought to Likert scale questions or

the responses they provide to these questions. Provision of alternate response formats such as rating scales have been described as acting as a "cognitive speedbump" (Harrison & McLaughlin, 1993), causing respondents to think in greater depth about the question and their response.

In addition, the rating scale response format was chosen because it enabled a number of items corresponding to a single question to be aligned. Students could then rank their answers to these items by visually comparing one response to the next. For example, the students were asked in one question to rate the importance of communicating with non-scientists. This question comprised two rating scale items in close proximity, one relating to the communication of technical details, the other relating to the social and ethical implications of science. By including both of these items within the same question, the students were able to attribute a level of importance to the second item relative to the level of importance they attributed to the first.

3.4.2.3 Piloting the Questionnaire

To improve the construct validity of the questionnaires (Oppenheim, 2001), the questionnaire was piloted with four undergraduate science students from another university in the state . One student was in the first year of their degree program, and other three were in the second year of their program. The questionnaire was administered to the pilot subjects in exactly the same way it was to be administered to subjects in the main study. After completing the questionnaire the subjects were interviewed and asked for feedback to identify any ambiguities in the questionnaire and whether or not they found any of the questions difficult to answer (See Appendix 6 for the pilot interview questions). The pilot interviews were audio-taped and analysed.

The results of the pilot interview analysis indicated the subjects took an average time of 12 minutes to complete the questionnaire, found the format and instructions for the questionnaire easy to follow, and had no difficulties in responding to the

questions using the rating scale format. While one subject indicated she would have preferred questions with a Likert-type response format, another indicated she liked the rating scale format because she it allowed her greater flexibility in her responses.

Any terms the subjects found difficult were discussed. These included *non-specialist public*, *media representatives*, *funders* and *campaigning groups*. All of these terms were chosen for consistency with the terminology used in *The Role of Scientists in Public Debate* survey (Wellcome Trust/MORI, 2000). After discussion with the pilot subjects it was agreed that misinterpretation of the terms *funders* and *campaigning groups* could be minimized by providing an example immediately following these terms in the questionnaire. In addition, the terms *non-specialist public* and *media representatives* were replaced with the terms *non-scientists* and *journalists*, respectively. For two items in the questionnaire, the term non-specialist public was not changed to non-scientist. These items were linked to the question *How would you rate the importance of communicating biotechnology research with the following groups*. As a number of the groups included as items in these two questions could be regarded as non-scientists, the term non-specialist public was retained.

In light of the pilot subjects' response to the term *non-specialist public*, the interview questions were also changed from *non-specialist public* to *non-scientist*. It was clear from the responses provided by the undergraduate students and the other stakeholder groups in the interviews that their understanding of *communication with non-scientists* was in keeping with engaging the public about science and technology. If there was any indication in the interviews that the stakeholders had not interpreted non-scientist in this regard, this term was discussed with the participant to ensure a shared understanding of the term.

3.4.2.4 Questionnaire Administration

The questionnaires were administered to undergraduate students at the end of lectures for first, second and third year science units. A brief introduction was provided by the researcher that summarised the aims of the research, the students'

role in the project, and instructions for how to mark answers on the rating scales. The students were encouraged to participate but the voluntary nature of the project was emphasised, as was the anonymity of the responses in the instrument.

The questionnaire was administered to 52 undergraduate students (19 males and 33 females) attending a lecture in a second year unit in the biotechnology program. This unit in animal biotechnology is compulsory for biotechnology students but is also available for students in other programs to attend. Twenty three of the students were enrolled in the biotechnology program (9 males and 14 females). The questionnaire was delivered during a lecture timeslot at the very end of the semester one. This lecture was chosen because the lecturer had informed the students that the format and questions in the final exam would be discussed, and this would promote a high attendance at the lecture, and therefore, a high response rate. Furthermore, the lecturer was positively disposed to allowing the questionnaire process to take up a significant proportion of her lecture timeslot as she felt she was unlikely to require the full lecture time allocated. The second year biotechnology students were given 20 minutes to complete the questionnaire. All students attending this lecture submitted a completed questionnaire at the end of the lecture.

The shortened questionnaire was administered to all students attending lectures in a first year science unit in introductory chemistry and a third year unit in molecular biology. Like the second year animal biotechnology unit, both of these units are compulsory for biotechnology students, but are attended by other science students, particularly the first year unit which is a core compulsory unit for many of the science programs in the division. In the first year unit, completed questionnaires were collected from 236 students (77 males and 159 females), of which 17 (11 males and 6 females) were enrolled in biotechnology. In the molecular biology unit, completed questionnaires were collected from 55 third year students (19 males and 36 females) of which 29 (16 males and 13 females) were enrolled in biotechnology.

3.4.2.5 Follow-up Interviews

Questionnaires comprising a high proportion of rating scales are convenient for data analysis involving large sample size and can be completed quickly by respondents. However, closed questions such as these can result in the loss of spontaneity and expressiveness. As Oppenheim states (1992), with closed questions "we shall never know what the respondents said or thought of their own accord". To obtain a better understanding of the reasoning behind the students' responses to the questionnaires, 13 second year undergraduate biotechnology students were interviewed. The students were interviewed in groups of two or three during a laboratory session of the second year animal biotechnology unit. These interviews were conducted two years after administration of the questionnaires with a different cohort of students, so the students interviewed had not seen the questionnaire prior to the interview. Each student was asked to complete the questionnaire and then describe the reasoning behind the answers they provided. The students were also asked whether or not they had completed the undergraduate unit in science communication, and what careers they planned to pursue after graduation. The interviews were audio-taped and transcribed verbatim. Each student was assigned a pseudonym to maintain the confidentiality of his or her responses. On average the follow-up interviews took 14 minutes to complete.

3.4.3 Interviews

Face-to-face interviews were undertaken with the remainder of the stakeholder groups: the doctoral students, early-career biotechnologists, lecturers and supervisors, science communication lecturers and science communicators (see Appendix 7 for each of the stakeholder group's Interview Schedules). The interviewees were sent a package of information at least two days (and usually one week) prior to the interview. The package contained a background information sheet, an information letter outlining the aims of the study, a consent form, the planned interview schedule and a copy of the questionnaire administered to the second year

undergraduate biotechnology students (see Appendix 8 for the Background Information sheet). The background information sheet defined the two key terms in the study – *science communication* and *civic science*. Both of these terms were discussed with each interviewee prior to the commencement of their interview to ensure a shared an understanding of the operationalisation of these terms between the researcher and the interviewee.

The interviewees were asked to complete the questionnaire in advance of the interview, with the aim of the researcher reviewing the responses provided and using this data to inform the questions asked in the interview. However, very few of the interviewees completed the questionnaire prior to the interview, and none returned a competed questionnaire in time for analysis prior to their interview.

The interviews were semi-structured which allowed for a conversational interview with two-way communication between the researcher and the interviewee (Oppenheim, 2001). While each interviewee was sent a copy of the proposed interview questions, it was indicated in the interview schedule that additional questions may be asked during the course of the interview. While each interviewee was asked every question on the schedule provided, the order of the questions varied according to how the interview proceeded and some novel questions arose during the course of the interview. This semi-structured interview format enabled exploration between the researcher and the interviewee of the issues raised during the interview. As various themes emerged in the data from each interview and its subsequent analysis, additional questions were added to the interview schedule for subsequent interviews. This interactive process of data collection and data analysis enabled an element of emergent design to be introduced into the case study (Erlandson, Harris, Skipper, & Allen, 1993)

The interview was undertaken in a location determined by the interviewee in order to increase participation rates and reduce the influence of investigator bias (Johnson & Gott, 1996). The consent form was signed and collected by the researcher prior to the interview. Interview field notes were made during and immediately after the

interview about each participant's mood and body language. Each interview was audio-taped and took approximately 30-45 min to complete.

3.4.3.1 Interview Questions

The interview questions were designed to address aspects of all three research questions and generate a rich description of the focus of the study by providing views of science communication and science communication training from multiple stakeholders' perspectives. Many of the interview questions were common for the lecturer, early-career biotechnologist, science communicator and science communication lecturer stakeholder groups. These interview questions, the research questions they address and the stakeholder groups responding to these questions is outlined in Table 3.

Table 3

Research Questions, Corresponding Interview Questions, and Stakeholder Groups Asked to Respond.

Research Question	Interview Questions	Stakeholder Group DS	ECB	L	SC	SCL
1. What is the current status of science communication education for tertiary biotechnology students in the case?	Have you been involved in any science communication activities or programs?	✓	✓	✓	✓	✓
	Please comment on any science communication training you received during your undergraduate training?	✓	✓	×	×	×
	Describe any science communication training you have had as part of your postgraduate training?	✓	✓	×	×	×
	Have you completed the generic skills training course offered to all postgraduate students?	✓	✓	×	×	×
	Have you had any science communication training since graduating?	×	✓	×	×	×
	Where would you seek science communication training?	×	✓	×	×	×
	How equipped do you feel to communicate your research?	×	✓	×	×	×
	Have you discussed communicating your research and its social and ethical implications to the public, with your supervisor?	✓	×	×	×	×
	Have you discussed communicating your research and its social and ethical implications to the public, with your employer or any of your fellow researchers?	×	✓	×	×	×
	Do you provide any science communication training to undergraduate or postgraduate biotechnology students?	×	×	✓	✓	✓
	Are you aware of any units (or components of units) offered to undergraduate or postgraduate biotechnology students in science communication?	×	×	✓	×	×
	How would describe the science communication education that biotechnologists currently receive as part of their tertiary training?	×	×	×	✓	✓
	How equipped do you feel early career biotechnologists are to communicate the technical details of their research to non-scientists?	×	×	✓	×	×
	Do you feel biotechnologists are sufficiently aware of the approaches they can or should take to science communication programs or activities?	×	×	×	✓	✓
	Do you feel biotechnologists are sufficiently aware of where they can seek help for science communication when they undertake science communication programs or activities?	×	×	×	✓	✓

DS = doctoral student, ECB = early career biotechnologist, L= lecturer, SC= science communicator, SCL = science communication lecturer, ✓= question asked of stakeholder group, ×= question not asked of stakeholder group

Table 3 cont...*Research Questions, Corresponding Interview Questions, and Stakeholder Groups Asked to Respond*

Research Question	Interview Questions	Stakeholder Group DS	ECB	L	SC	SCL
2. How may the stakeholder' views of science communication impact on the provision of civic science training for undergraduate and postgraduate students in the biotechnology program?	How successfully do you feel biotechnology is currently communicated to non-scientists?	×	✓	✓	✓	✓
	What role do you feel biotechnologists should play in communicating biotechnology research and its social and ethical implications to the non-scientists?	×	✓	✓	✓	✓
	What role do you feel early career biotechnologists should play in communicating biotechnology research and its social and ethical implications to the non-scientists?	×	✓	✓	✓	✓
	Do you feel biotechnologists need to change their current approach to communicating their research and its social and ethical implications?	×	✓	✓	✓	✓
3. What are the stakeholders' views of science communication training for undergraduate and postgraduate students in the biotechnology program?	Do you think science communication training should be a component of tertiary education for biotechnology students?	×	✓	✓	✓	✓
	Do you feel the skills required for communicating research to non-scientists differ from those required for communicating with fellow scientists?	×	×	✓	✓	✓
	Are you aware of any supports provided for the provision of science communication education at the undergraduate or postgraduate level?	×	×	✓	✓	✓
	Can you identify any barriers to the provision of science communication education at the undergraduate or postgraduate level?	×	×	✓	✓	✓
	Would it be feasible to introduce science communication training into the current biotechnology curriculum?	×	×	✓	✓	✓
	What do you think would be the outcome of improving the science communication training of early-career biotechnologists?	×	×	✓	✓	✓
	Do you think the science communication capacity of biotechnologists can be improved by science communication training?	×	×	×	✓	✓
	Do you feel the skills required for biotechnologists to communicate their research with non-scientists differ from those required for communicating with fellow scientists?	×	✓	✓	✓	✓
	Is generic communication skills training sufficient for training a biotechnologist to be a science communicator?	×	×	×	✓	✓

DS = doctoral student, ECB = early career biotechnologist, L= lecturer, SC= science communicator, SCL = science communication lecturer, ✓= question asked of stakeholder group, ×= question not asked of stakeholder group

3.4.3.2 Doctoral Student Interviews

Seven postgraduate biotechnology students (4 males and 3 females), all enrolled in doctoral studies, were interviewed about their experience with, and views of, science communication and science communication training. The students were recruited for participation in this case study by asking all supervisors of postgraduate students enrolled in doctoral studies in the case to nominate their students for participation. All postgraduate biotechnology students in the biology and biotechnology program were also emailed and asked to participate in this study.

The doctoral students were asked at the beginning of the interview to describe their research project and the career they intended to pursue once they had graduated from their doctoral studies. The research projects the students were enrolled in were wide-ranging and included agricultural biotechnology, environmental biotechnology, microbial signal transduction, plant biotechnology and medical biotechnology. Four of the research projects were aimed at a specific commercial application. Six of the students graduated with Honours from the university the case study was undertaken. The other was an international student with undergraduate and master's degrees from an alternate university. All students were expecting to submit their thesis within a year of the interview date. Four of the students had progressed directly from the undergraduate degree straight into doctoral studies. The remaining three had less than two years work experience prior to commencing their doctorate and this work experience did not involve any involvement in public engagement activities or science communication training (with the exception of one student who had a single interview with a journalist from a local farming paper).

The doctoral students were also asked in their interviews to define science communication, to indicate how aware are they of the science communication training available to them at the university, and describe their views of the science communication training they receive.

3.4.3.3 Undergraduate Lecturer Interviews

All lecturers in the case who teach compulsory units in the biotechnology program were invited to participate in the study. All ten lecturers approached (9 males, 1 female) agreed to participate in the study. The participants ranged in seniority from lecturer (n = 3) and senior lecturer (n = 3) to associate professor (n = 4). All were coordinators of at least one biotechnology unit, one was head of the program, and another was head of the school from which the program is offered. On average, the lecturers had been teaching in the program for 16.6 years (ranging from two to 30 years), and all were currently supervising, or had supervised, postgraduate biotechnology students.

The interview questions explored the lecturers' views of science communication training, their awareness of the science communication training offered to the biotechnology undergraduate students in the program and whether or not they deliver any science communication material in the undergraduate units they teach.

3.4.3.4 Early-career Biotechnologists Interviews

During the undergraduate lecturer interviews, the lecturers were asked to provide details of biotechnology graduates, with or without postgraduate qualifications, who were currently employed in the biotechnology field and may be interested in contributing to the present study. The lecturers identified a number of early-career biotechnologists who they felt would be interested in participating in an interview and these early-career biotechnologists were contacted by email. Six early-career biotechnologists (1 male and 5 female) agreed to participate in the study and were subsequently interviewed.

The interview questions for the early-career biotechnologists addressed their views of science communication training, their awareness of the science communication training offered to the biotechnology undergraduate students in the program,

3.4.4 Additional Contextual Data

To supplement the case study data, additional contextual data regarding science communication and the science communication training of science students was obtained from three science communication lecturers. These lecturers are the coordinators of three different science communication units. One of these coordinators, Charles, teaches the science communication unit offered to the students in the case. He is an associate professor in science education in the arts faculty of the university and teaches graduate and undergraduate units in science education, science communication and information and communications technology in education. His research and professional interests include the public understanding of science and technology.

The other two science communication lecturers, Cate and Tess, coordinate science communication units in other universities in the state. These universities do not offer degree programs specifically called biotechnology, but they do offer molecular biology programs whose content is similar to the content to the biotechnology program which forms the focus of the present case study. Cate is a senior lecturer in science communication within a science faculty. She had 20 years of experience in crop science and molecular biology before taking a science communication lecturing position. She teaches units in science communication that form part of the science communication studies offered by her university. These studies include a bachelor degree, graduate certificate, graduate diploma and research degrees in science communication. These courses aim to "provide opportunities to develop important skills in science communication, IT literacy, electronic publishing and related areas as well as communication research to develop scientists who will be able to communicate the discoveries of research in a way that can be understood by the community and the world of business and industry". The undergraduate degree in science communication provides the students with an opportunity to combine science communication with a variety of science disciplines. The science communication units within this degree are available to all science undergraduate students at the university to include within their chosen program.

The other science communication lecturer, Tess, was a senior lecturer in technology studies within the science faculty of an alternate university to Charles and Cate. She began her career as a physicist, completed a diploma in education and taught secondary science before completing a doctorate in science, technology and society and beginning lecturing in this area. Before retiring in 2005 she taught three science communication related units to undergraduate student in the division at her university. One unit was compulsory for the first year conservation biology students at the university and an elective for other first year science students, including students enrolled in the molecular biology program. The other two units were offered as elective units to all science students at the university.

Additional contextual data was also obtained from a number of professional science communicators in the state who are affiliated in some way with the biotechnology profession. Members of the state branch of the ASC with links to biotechnology research were invited to participate in this study. Seven (1 male and 6 females) of the eight science communicators approached agreed to participate in the study. Four of these communicators had undergraduate science qualifications, and one had a postgraduate master's degree in science. The other two had undergraduate arts qualifications.

The science communicators and science communication lecturers were provided with identical interview schedules. The questions contained in this schedule aimed to address these communicators' experience in science communication in the area of biotechnology, and their understanding and views of science communication education.

3.5 Data Analysis

3.5.1 Analysis of Quantitative Questionnaire Data

The 343 questionnaires were analysed as outlined below. The items on the questionnaire were not numbered, however, significant left and right margins were allowed to facilitate easy coding of the data. To provide a unique identity to each returned questionnaire a case number was assigned to each questionnaire returned. After collecting the questionnaires, each was given a unique code in the upper right hand corner corresponding to the unit in which the questionnaire was delivered and a number (for example 1-1). For each item in each questionnaire, the section and item number was entered into the adjacent right margin adjacent and the code was entered onto the left hand margin. For the dichotomous data this consisted of 1 or 2. All questionnaires were coded by the researcher, thereby avoiding any systematic bias that may have arisen if a number of individuals with different approaches to data coding were involved in the analysis.

The rating scale responses in the questionnaires were scored by measuring the distance in cm (to the nearest mm) from the left hand end of the line to the centre of the subject's cross on the line. The results were entered into the left hand margin of the questionnaire and then transferred into a Statview spreadsheet (SAS Institute Inc). As respondents are thought to be unable to make discriminations that are finer than ten points or so using rating scales (G. A. Miller, 1956), the data was collapsed into 10 categories (0-9) by transforming the data into its absolute value. The resulting ordinal data was then analysed using non-parametric tests in Statview (Huck & Cormier, 1996). For comparison of independent items the Mann-Whitney U test and Kruskal-Wallis one way analysis of variance test were applied to the data. For comparison of the rating of items related to the final question the Wilcoxon matched pairs signed ranks test and Friedman two way analysis of variance of ranks tests were used. Bonferroni adjustment procedures were applied to all post hoc analyses.

Box plots, also known as box-and-whisker diagrams, were used to depict the students' rating scale responses (Huck & Cormier, 1996). These plots show the median and the inter-quartile range as a box that starts at the lower quartile and stops at the upper quartile range. The median is represented by the vertical line in the box and the whiskers that extend from either end of the box indicate the range of the data.

3.5.2 Analysis of Qualitative Questionnaire Data and Interview data

The recommended approach of Glaser and Strauss (1967) was used to analyse the data obtained from the qualitative components of the questionnaires (the open-ended questions) and the interviews. Deductive categories were developed from the literature review, research questions and working hypotheses. From the emerging themes, grounded theory was developed then verified and assessed using negative case testing (Denzin, 1978). This iterative process involved identifying data that did not fit the proposed hypothesis, and either discarding or reformulating the hypothesis in order to account for this data, or excluding the data. The complete data set was then reanalysed in light of these changes.

This analysis was performed using NVivo (QSR International, 2002). First, the interviews were transcribed verbatim and each interviewee was assigned a pseudonym to maintain the confidentiality of his or her responses. Some minor changes were made to the transcripts to correct grammatical errors. The transcripts were entered into NVivo, and coded initially according to the order of the questions indicated on the interview schedule. For each question, the data was then coded according to emergent themes, commonalities, and disparities. These themes were then explored across the questions (See Appendix 9 for the summary of the NVivo-assisted coding of the qualitative data).

3.6 Design Quality

A major strength of the case study is the ability to build data triangulation into the research design and use many different sources of evidence for data collection (Yin, 2003). Elements of triangulation were built into the present doctoral case study by using multiple sources of evidence (questionnaires and interviews) to collect data from multiple stakeholders in the case (undergraduate and doctoral students, lecturers, supervisors, early-career biotechnologists and science communicators). By triangulating both the data collection methods and the data sources, a rich description of the focus of the study – that is, science communication, biotechnology and tertiary education - was generated. Triangulation, however, is only one way in which constructivist research demonstrates its methodological trustworthiness. Other measures of goodness and value were built into the design of the present doctoral study.

The credibility of this study is reflected in the measures taken by the researcher to ensure the subject's degree of confidence in the truth of the findings. At the commencement of all interviews, the interviewees were informed they could request an audio copy of their interview or a complete transcript of their interview. The interviewees were also informed they would receive a summation of key points resulting from the analysis of the transcripts and any quotes that would be used to represent their views. All interviewees were sent these interview summaries for member checking and asked to indicate if they felt the summary of their interview, particularly the researchers' interpretation of their responses and the quotes presented, accurately represented their views (See Appendix 10 for examples of the member checking letter and three examples of the member checking documents sent to interviewees). In addition, 15 interviewees were asked a series of additional questions. The questions aimed to clarify the researcher's understanding and interpretation of the interviewees' comments obtained in the interview and/or to further explore questions that the researcher felt were not explored in sufficient depth in the interview. This process also enabled the researcher to ask the early interviewees questions that arose in later interviews.

The participants were given the opportunity to reply by email or telephone and comment on the contents of the transcripts or summaries, and/or reply to the questions posed by the researcher. Interviewees were informed in the covering letter that if the researcher did not hear from them by a set date three weeks later, it would be presumed they were in agreement with the summation of the interview. A reminder email that included both the covering letter and interview summation was resent to the interviewees one week before this specified date.

Thirteen of the 27 interviewees contacted for member checking purposes responded to the researcher (three doctoral students, two early-career biotechnologists, four lecturers, three science communicators, and two science communication lecturers). Six of the interviewees were not contactable. Four of the doctoral students had submitted their thesis for examination or had graduated from the university. One early-career biotechnologist had left his place of employment, and one of the science communication lecturers had retired. All 13 of the respondents indicated they were in agreement with the interview material. Four interviewees added some further comments to their initial responses. Four of the interviewees that were posed specific question in the member-checking process answered these questions.

In addition to the member-checking process outlined above, the credibility of this case study is also reflected by the persistent observation of the case by the researcher. The researcher was a lecturer in the program for seven years. For four of these years she was concurrently collecting data for this doctoral study and during this period maintained long-term observation of the case and stakeholder groups. In addition, the credibility of the case was also improved by collection of reference materials to provide a broader view of the context of the case. The exploration of additional perspectives of the focus of the study by stakeholders that were linked, but not part of, the case study, provided a holistic view of the degree program and the science communication training of scientists. Significant levels of debriefing were also undertaken between the researcher and her supervisors as part of the doctoral research process, and other associates at research conferences and presentations.

These debriefing sessions provided valuable feedback that enabled the case study to be refined as it progressed.

An audit trail was also established to allow for the dependability of the case study to be measured. By providing documentation and an account of the process of the research undertaken in the case study in this thesis document, the processes by which the study was conducted have been made transparent. The raw data (questionnaires, audiotapes and transcripts) for this study has been filed, stored and protected in the researcher's office. Documentation of the data analysis, including the coding used in the NVivo-assisted analysis, is provided in the appendices of this thesis.

The transferability of this case report, that is, the extent to which the findings can be applied in other contexts or to other respondents, was also taken into consideration when designing the present case study. This study centres on a biotechnology program because this field of science is seen as *the* emergent technology of the century and thus it may serve as a useful model for other emergent technologies. In addition, biotechnology is a highly contentious and controversial area of science and there is a perceived need for biotechnologists who are capable of communicating the technical, social and ethical complexities of the field (Gregory, 2003). Through the choice of the particular discipline and the structure of the program it is anticipated that the report generated from this present doctoral study will be transferable at the very least to other biotechnology programs, and potentially transferable to any other program involving the delivery of material linked to an emerging field of science which may or may not involve technological controversy. Thus the recommendations generated from this study may be useful for any field where technological controversy exists and public engagement needs to be improved.

4. CURRENT STATUS OF SCIENCE COMMUNICATION TRAINING IN THE BIOTECHNOLOGY DEGREE PROGRAM

The aim of this present thesis is to address the overarching research question of *how biotechnology education at the tertiary level can best prepare science graduates for a civic science role.* The quantitative and qualitative data pertaining to this overarching research question is presented in the following three chapters, with each chapter pertaining to one of the research questions. The present chapter presents the data pertaining to Research Question 1 which examines the current status of science communication education for tertiary biotechnology students in the case. In Chapter Five, which relates to Research Question 2, the stakeholders' views of science communication and how they impact on the provision of civic science training for undergraduate and postgraduate students in the biotechnology program is explored. Research Question 3 is explored in Chapter Six, which addresses the stakeholders' views of science communication training for undergraduate and postgraduate students in the biotechnology program.

The present chapter explores the level of understanding of science communication among biotechnology students, how they feel their training prepares them for civic science, and what their awareness and level of participation in science communication training is. The chapter also examines how well equipped early-career biotechnologists feel to undertake civic science, how the lecturers' perceive science communication training in the degree program, and how science communicators' view of the science communication training that biotechnologists currently receive as part of their undergraduate and postgraduate training. In total, data are presented from 69 completed questionnaires obtained from the undergraduate biotechnology students in the case study, and 36 interviews undertaken with 13 undergraduate students, seven doctoral students, six biotechnology early-career biotechnologists and 10 lecturers is presented. Further contextual data obtained from an additional 274 questionnaires collected from undergraduate students enrolled in undergraduate science programs other than

biotechnology, and from interviews undertaken with seven science communicators and three science communication lecturers, is also provided.

In the questionnaire administered to the second year biotechnology students, the current status of the science communication training for tertiary biotechnology students in the case study was explored by asking the students to define science communication. In the interviews, the doctoral students and early-career biotechnologists were asked to indicate whether or not they had received any training in science communication and asked to describe any experience they had in communicating science, particularly with non-scientists. The lecturers were asked if they incorporate any science communication training into their teaching practice and their awareness of where science communication training is offered to the biotechnology students in the case. The lecturers were also asked in their interviews to describe their own experience in science communication.

In addition, seven science communicators and three science communication lecturers were interviewed. They were asked to comment on their perception of the science communication training that biotechnologists currently receive as part of their undergraduate training program. These stakeholders provide an external perspective of the science communication training that undergraduate biotechnology students receive.

4.1 Undergraduate Biotechnology Students' Understanding of Science Communication and Awareness of Science Communication Training

In the questionnaire delivered to the 23 second year biotechnology students, the students were asked to define science communication in their own terms. The aim of the first question was to determine the students' understandings of science communication in light of the level of training they receive in this area. In contrast to the other stakeholder groups in the study, a definition of science communication had not been provided to these students or discussed with them prior to the questionnaire.

Difficulties in defining science communication, and public engagement in particular, have been acknowledged in the literature (Royal Society, 2005; Stocklmayer, Gore, & Bryant, 2001). Given the complexity of the term and the lack of science communication training these students receive, this question was not asked in order to see if these students could generate a lengthy or comprehensive definition of science communication. Rather, this question was asked to determine these students' understanding of the scope of the term (Does science communication include scientist-to-scientist communication and public engagement?) and its purpose (What should science communication aim to achieve?).

When asked to define science communication in their own terms, five of the students either left this question blank or indicated they did not know how to define this term, by writing comments such as "I don't know", or providing a non-specific answer such as "the communication of science". Of the 18 students that attempted to provide a definition of the term, six indicated by their answers that they felt science communication is limited to the communication of scientific knowledge between fellow scientists. For example one student defined science communication as "Writing review papers, lab reports etc that communicate your thoughts and understandings to the scientific community". There was no indication by these six biotechnology students of the potential for scientists to communicate science with audiences broader than their peers.

Only 12 of the 23 undergraduate biotechnology students surveyed indicated the potential for the engagement of non-scientists in science communication, and only two phrased their responses to suggest this form of communication could involve an active exchange of information between scientists and non-scientists. One of these students stated "It means how to communicate science with the public". The remainder used language suggestive of a one-way transfer of information from scientists to a passive audience of non-scientists. One student emphasised in his definition that this one-way information transfer should aim for public acceptance of biotechnology, stating science communication is "communicating the aspects of science to the mass population for social understanding and acceptance". Another

defined science communication as "The transmission of scientific knowledge and news to the community".

The students were also asked if they were aware of the science communication unit offered by the University and if they intended to enrol in this elective unit. The aim of these questions was to provide an indication of their awareness of, and their willingness to participate in, science communication training. None of the undergraduate science students in the case had enrolled in the science communication unit, and less than a quarter indicated an intention to enrol.

The second year biotechnology students that were interviewed were also asked if they were aware of the science communication unit and if they intended to enrol. Of the 13 undergraduate students interviewed, none were aware the unit existed and none intended to enrol in it. These students were also asked in their interview to describe their preferred choice of career after graduating. Ten of the students planned to pursue research careers in biotechnology, two indicated they would like to work in forensic diagnostic laboratories, and one was undecided. None indicated they would be planning a career in science communication.

Finding 1: Most undergraduate biotechnology students surveyed had a limited understanding of science communication, and very few viewed science communication as involving an exchange of information between scientists and the community. None had completed the elective science communication unit offered and very few were aware the unit existed.

4.2 Doctoral Students' Experience of Science Communication

In the doctoral student interviews, the seven students interviewed were asked to describe their area of research, their science communication experience and how well they felt their undergraduate degree had prepared them for communicating their

research. Their area of research is summarised in Table 4. The doctoral students were also asked to indicate their awareness of the communication skills course available to them and their intent to enrol in this postgraduate skills course. Prior to their interview these students had been provided with a definition of science communication.

Table 4

Doctoral Student Research Topics

Student name (pseudonym)	Doctoral studies topic
Rebecca	Environmental biotechnology: Nutrient removal from waste water
Susie	Agricultural biotechnology: Genetic modification of plants
Georgie	Agricultural biotechnology: Plant recombinant antibodies and fungal resistance
Steven	Agricultural biotechnology: Molecular basis of resistance to plant viruses
Danny	Molecular biology: Signal transduction in bacteria
Andrew	Medical biotechnology: Serological assay development
Marcus	Molecular biology: Gene expression in rumen bacteria

All of the doctoral students interviewed, with the exception of Rebecca, indicated they had communicated their research with fellow scientists either as a poster or oral presentation at a science conference. Rebecca indicated she had not communicated her results to anyone other than her immediate research group as communication of her results was restricted by proprietary issues. A formal arrangement with the company that funded her research restricted all forms of communication about her research.

Five of the seven doctoral students indicated they had not communicated their research to anyone other than their fellow scientists. The two doctoral students who

did report experience in communicating with a broader audience however, clearly indicated their support for the communication of science with non-scientists. While both students had very limited experience in this area (one student had been interviewed once by a journalist from a local farming paper prior to commencing doctoral studies and the other had been interviewed on a single occasion for an internal university publication), both commented on the importance of communicating with non-scientists. Susie stated "I think there certainly needs to be more communication" (October 4, 2001). Steven stated:

> Giving the talk was a very, very useful exercise because in this field not only do we regularly present our work to other scientists, we also occasionally need to present to the general public. So it gives us practice to transfer the knowledge of our work across to the wider community. You can be a good scientist but if you can't communicate your work then there is no use doing the work as no one will understand your work. So I think giving presentations and all that type of thing is very important. Communication of your work is an important part of science, it's not just the lab work. (Steven, October 12, 2001).

Steven, however, expressed the view that his current project was not ready to be communicated with non-scientists:

> So if you're doing research into cancer or something, it could be, the public could be interested. Whereas basic research like my project - where I'm looking at differences between two different viruses – no-one's probably going to worry about it. Maybe in five or 10 years when I've actually got a plant that's resistant to the virus, then they'd love to know like, oh, the plant's resistant. But I don't think every project can be presented to the public..... It has to be interesting or no-one is going to listen. (Steven, October 12, 2001)

Finding 2: The majority of doctoral students had communicated their research with fellow scientists. The two students who had been involved in public engagement activities expressed positive views of public engagement.

The doctoral students were also asked if they felt they had received any science communication training during their undergraduate or postgraduate years of study. Five of the students indicated they felt their undergraduate biotechnology program had not provided them with any form of training in science communication. Two indicated they felt their degree had provided them with "some" training, but when the time came to present their doctoral research they did not feel this training had adequately prepared them to give their talk. Rebecca stated "Presentations are also something we did do quite a bit around that period we had the [first year] course……but I wasn't prepared to get up in front of people" (November 14, 2001).

When asked about their postgraduate science communication training, none of the doctoral students interviewed had completed the generic communication skills course available and none planned to enrol. Two of the students were unaware the course existed. They had discussed public engagement with their supervisor, but had not been encouraged to enrol in the communication skills course. Five of the seven doctoral students, however, indicated they perceive the ability to work independently of their supervisors to be part of their training. Georgie said "Until I realised that everything has to be done by myself, then I wasn't really worried about that. But at the beginning it was a bit hard for me" (November 23, 2001). Susie stated:

> I'm basically on my own unless I need help… Sometimes there's a bit of a lack of communication but he's never said 'No I can't see you'. But it has to be my own initiative. But I guess that is part of PhD training. (Susie, October 4, 2001)

Finding 3: The doctoral students expressed the view that their undergraduate training did not prepare them for communicating with scientists or non-scientists.

While many were aware of the postgraduate generic skills training available, none had enrolled or planned to enrol. None had been encouraged to enrol by their supervisors although many expressed the view that that working independently of their supervisor was an important component of their doctoral training.

4.3 Early-career Biotechnologists' Experience of Science Communication and Science Communication Training

In their interviews, the six early-career biotechnologists were asked to describe any experience they had in communicating their research and any science communication training they had received. They were asked if they felt their undergraduate degree had prepared them for communicating, and if they had been provided with any science communication training since graduating. To determine if training and experience in science communication has any bearing on how equipped the early-career biotechnologists feel with respect to science communication, the early-career biotechnologists were also asked to describe how equipped they feel to communicate both the technical aspects of their research, and the social and ethical implications of their research.

When asked to describe any science communication activities or programs they had been involved in, four of the six early-career biotechnologists indicated they had little or no formal experience in communicating with non-scientists. Their area of employment, length of employment, and/or qualifications of the early-career biotechnologists did not appear to impact on their participation in public engagement activities (see Table 5).

Table 5

Early-career Biotechnologists' Position of Employment, Qualifications and Science Communication Experience

Early-career Biotechnologist	Position	Years of Employment as Biotechnologist	Qualification(s)	Science Communication Experience (Y/N)
Linda	Forensic Scientist	4	BSc MBA	Y
Anne-Marie	Biotechnology Technical Assistant	5	BSc Hon PhD	N
Mary	Forensic Scientist	4	BSc Hon	N
Matthew	Biotechnology Technical Assistant	2	BSc Hon	N
Rosie	Medical Scientist	4	BSc Hon	Y
Natalie	Environmental Biotechnologist	4	BSc Hon	N

Of the two early-career biotechnologists who did report having experience in communication with non-scientists (Rosie and Linda), only one of these was required to communicate as part of her employment. Rosie's job as a medical scientist requires her to recruit patients, and she indicated she communicates regularly with a variety of patients and clinicians. She stated "Most of the communication I do is explaining what we do to the lay people. I mean, I work in hospital so I would be explaining what we're doing to patients and trying to get them to understand what we're doing and understand why we're doing what we're doing" (February 28, 2006).

In contrast to Rosie whose job involves an intrinsic communication component, Linda's position as quality assurance officer within a forensic laboratory does not

require her to communicate to audiences broader than her fellow scientists. However Linda indicated in her interview that she volunteers to talk about forensic DNA technology at lectures for both the public and undergraduate science students. While she seeks out these roles, she represents her company when she provides these lectures, and is therefore supported by her employer in this role through the provision of work time to prepare and present these lectures.

Finding 4: One third of the early-career biotechnologists have been involved in science communication activities directed towards public engagement, either as part of their employment or of their own accord.

When questioned about their science communication training, all of the early-career biotechnologists indicated that they felt the undergraduate biotechnology program had not provided them with any form of training in this area. Linda, while acknowledging that she had been provided with some coaching in how to give oral presentations in her undergraduate units, noted that these presentations were often avoided by her fellow students without penalty:

> The problem was, even with those oral presentations, there was ways you could get out of it for those people who really didn't want to do it. Like you'd get in a group and then just be the one who sits back and changes the overheads…so you could avoid it. So that was a bit – I wouldn't say that was really good training necessarily. (Linda, November 22, 2005)

When asked if they had been provided with any form of science communication training since graduating from their undergraduate biotechnology program, four of the six early-career biotechnologists indicated they had not. The two exceptions, Rosie and Linda, were the two early-career biotechnologists who indicated they had some experience in science communication. Rosie indicated she had had some "on-the-job training" in how to recruit patients by her supervisor, but felt this training was limited (February 28, 2006). Linda, in contrast, indicated that she had had significant science communication training since graduating. Prior to her taking on

her current forensic quality assurance role, Linda indicated she had voluntarily undertaken a media awareness course run by the Australian Broadcasting Commission for science researchers on how to promote their research through the mass media. While her attendance at this course was supported by her employer through the provision of time to attend the course, it was not organised as part of Linda's workplace professional development. Linda applied to attend this course independent of her workplace. She stated:

> I think that's [the media training course] probably taught me a lot about what scientists need to get into...It wasn't at all about how to become a science communicator. It was about how to get your science into the media, what each of the forms is looking for. And so, I mean, that was really, that was fantastic, that experience there. (Linda, November 22, 2005)

Finding 5: None of the early-career biotechnologists expressed the view that their undergraduate degree provided them with any form of training in science communication, and few had been provided with any training in this area since graduating. The two early-career biotechnologists who had been given training in this area were actively involved in science communication, one as part of her work.

When asked to describe how equipped they felt to communicate their research, Linda and Matthew indicated they felt well equipped to communicate both the technical aspects of their research and the social and ethical implications of their research with non-scientists. Matthew expressed the view that his science communication skills and confidence came not from his biotechnology training but from his prior experience as a sports coach and as a small business operator (he ran his own electrical business for 20 years prior to commencing undergraduate studies in biotechnology). Despite indicating he felt he had these skills, however, Matthew reported little science communication experience in his role as technical officer for a high school teaching laboratory, other than running extension courses in biotechnology for advanced science students in high school.

Three of the early-career biotechnologists, Natalie, Rosie and Mary, felt equipped to communicate the technical aspects of biotechnology but not the social and ethical implications. Natalie indicated that at this early stage of her career her choice of employment had been based primarily on economic imperatives, rather than a conscious decision to work in a particular area after consideration of the social and/or ethical factors related to that research area. She stated:

> Most of the jobs that I've taken, prior to starting my PhD, I took because the job was there and I needed the money. So not because I had a, you know, I had to think to myself is this really the sort of job that I really want to do...So I think in some ways the economic imperative of making sure that you get a grant or that you get another job or whatever stops you really from thinking those sorts of things. (Natalie, February 16, 2006)

Natalie felt she had not had sufficient opportunity to reflect on the social and ethical implications of her work, and as a consequence she did not feel comfortable about communicating with non-scientists about this side of her research.

Rosie felt she could communicate comfortably about the technical details of her research, but felt uneasy about discussing the social and ethical implications of biotechnology. Unlike Linda, her science communication training did not extend beyond public engagement at the technical level, and she was conscious of "over-stepping boundaries" and discussing biotechnology beyond her realm of experience:

> Unless there's a subject that I'm really confident about I probably wouldn't delve into a particular area. I'd probably direct them to someone who's more experienced or would deal with a subject every day...I probably wouldn't be that confident to go any deeper than the basics if someone approached me. (Rosie, February 28, 2006)

Mary indicated she felt ill-equipped to communicate either the technical or social and ethical implications of biotechnology. She did not report having any experience in

science communication, did not see it as part of her job description, and did not feel she had any been provided with any training in this area.

Finding 6: Though five of the six early-career biotechnologists expressed the view that they equipped to engage with the public about the technical aspects of their research, only three felt equipped to engage with the public about the social and ethical implications of their research. Those who were provided with training in science communication felt well equipped to communicate.

4.4 Lecturers' Provision of Science Communication Training

The ten lecturers interviewed in the biotechnology program were asked to describe the science communication training they provide to biotechnology students in the course of their teaching, and if they were aware of any other science communication training offered to the students in the case. They were also asked to describe their biotechnology lecturing experience (Table 6) and their experience in communicating with non-scientists to see if their level of experience in these areas had any bearing on their provision of science communication training to students.

Table 6

Biotechnology Lecturers' Position and Years of Lecturing Experience

Lecturer	Position	Years of Lecturing
Alan	Professor	30
Pierce	Assoc Prof/ Biotechnology Program Chair	27
Hamish	Assoc Prof/ Head of School	27
David	Assoc Prof	16
Owen	Senior Lecturer	No answer provided
John	Senior Lecturer	2
Gareth	Senior Lecturer	17
James	Lecturer	15
Abbey	Lecturer	10
Richard	Lecturer	15

All of the lecturers interviewed indicated they taught science communication to undergraduate and postgraduate students in some form. For the majority (n=8), the sole extent of this training was directed towards developing the students' skills in communicating with other scientists, particularly how to prepare scientific reports. One lecturer indicated he felt that too much emphasis has been placed on teaching scientific report writing skills, and this could be redressed by increasing the level of generic communication skills training in the undergraduate program:

> There's probably been within our school a bit of an over-emphasis on scientific writing in terms of all the lab reports. We actually analyse the number of lab reports a student might have generated over the course of a three year degree – it's just an enormous number. And if we're just being serious about that we'd say look, we've done an overkill on that. We should be trying to identify ways and means of cutting that down so some units don't have that requirement, and instead they'd take on the responsibility of more oral presentation skills or whatever. (Hamish, October 20, 2005)

Only two lecturers, John and Abbey, delivered any material aimed at providing undergraduate students with skills in how to communicate with audiences broader than their scientific peer group. Both of these lecturers acknowledged the training they provided in science communication was "informal" and unassessed. Abbey felt the students needed to be exposed to sufficient science communication training to enable them to appreciate their civic science obligation:

> I don't do anything formally that is called science communication. However I certainly model in teaching practices that I use, and encourage in the students in whatever the activities are that we're doing, that they must communicate well. And that is one of the graduate attributes to which we work for our students. And I see as a scientist it's really important because we're so dependent upon acceptance and understanding. And if we want to be – I call it a responsible citizen - whatever we do in our lives we should be able to share it with others and be part of the community. (Abbey, October 20, 2005)

Finding 7: The majority of the lecturers claim they provide science communication training in some form to the undergraduate biotechnology students, but most restrict this teaching to the delivery of material aimed at improving formal report writing skills. The two lecturers who incorporate aspects of civic science into their teaching do this informally and the material delivered is not assessed.

The lecturers were also asked in their interviews if, and where, they felt science communication was taught to the biotechnology students in the case. While all of the lecturers were able to identify units that provided the undergraduate students with report-writing skills, none could identify where the students were taught to communicate with non-scientists. This finding is not unexpected given none of the lecturers reported providing any formal training in this area. When the lecturers were asked specifically if they were aware the university offers biotechnology students an elective unit in science communication, only three of the lecturers interviewed (Richard, Pierce and Abbey) indicated they knew this unit existed. These lecturers

were neither the most senior of this group, nor had they taught within the biotechnology program the longest.

Richard indicated he knew very little about the unit other than its existence. For this reason he did not promote enrolment in this unit to any of his students:

> I'm actually not even aware of what course it's part of, but I'm only aware that it exists and it's over there...Personally I don't know any of our students who have done that course or even are aware of it because I don't think most of the staff are aware of it. (Richard, October 13, 2005)

Pierce, the program chair of biotechnology is responsible for counselling students about the composition of their degree program and their choice of elective units. He indicated he recommends the unit to students seeking advice on possible electives, but finds the uptake of his advice to enrol in this unit very low. Abbey also indicated she encourages her students to consider the unit for inclusion within their program, but personally has reservations about the relevance of the course for biotechnology students because it is not delivered from within the science division. She stated "It comes out of an educational framework - the science teachers' framework - and I believe the emphasis is different than if I were to frame a course for science communication for scientists" (Abbey, October 20, 2005). Abbey felt the low level of enrolment of biotechnology students in this unit is linked to the low value these students attribute to gaining science communication skills, especially those planning to pursue mainstream careers:

> It really depends what the competition is in terms of electives. Students like to measure value in the units that they buy and it really depends how we sell that value and what value we provide.....For the individual student at under-graduate level the value [of science communication] will not be immediately apparent.....They like to be able to say 'I've done this sort of molecular biology, I've done this sort of cell culture, I've done this sort of physiology',

> so that they have a package when they go for jobs. They can say they've done things. It depends where they think they're going. For some people [students] science communication may be a good package, but for the average person who sees themselves down a research training pathway, it mightn't be a good selling point. (Abbey, October 20, 2005)

Finding 8: All lecturers were able to identify where in the undergraduate program the students are offered training in report writing skills, but none could identify where the students are taught the skills required for public engagement. Only a minority of the lecturers were aware the university offers a unit in science communication. Only two lecturers recommend this unit as an elective to the students, and one of these lecturers expressed reservations about the value of the unit.

The lecturers were also asked in their interviews to describe their personal experience in science communication, in particular, any activities involving engagement with non-scientists. The purpose of this question was to determine if participation in science communication has any influence on delivery of science communication training by these lecturers. Half of the lecturers (n=5) indicated they had some experience in this area. Four lecturers described significant involvement in communicating with non-scientists including interactions with the mass media, liaison with policy-makers and government departments, school students and the general public. Two of these lecturers were John and Abbey – the only lecturers who indicated they taught communication skills beyond peer communication (albeit informally). The other two lecturers who indicated some experience in science communication (David and Alan) described only limited experience in communicating with non-scientists. David felt most of his communication with non-scientists was "ad hoc" (February 16, 2006) and Alan felt his science communication efforts were often directed more towards "the policy level than the public consumption level" (December 9, 2005).

Five lecturers indicated they had little or no experience in communicating with non-scientists. Richard, who does not teach any science communication skills to his students, indicated he has no experience in communicating science to anyone other than the scientists in his immediate area of speciality. He indicated that communicating with non-scientists was not even in his consciousness prior to the interview, and qualified all his comments with the proviso that his views did not come from an informed position:

> I'm very limited in terms of communicating with anyone in the community other than narrow scientists in my field of science. My experience in science communication is minimal and not something that features at the front of the consciousness even in the process of being a lecturer here. Which is surprising and a little bit shocking. But that's the reality. (Richard, October 13, 2005)

Richard indicated that while he felt comfortable teaching students how to communicate with their peers, he did not deliver any material related to how scientists can engage with the public as a direct result of his inexperience in this area:

> But in terms of by the means, the training, the education in wider science communication – no. And one of the reasons would be that I've no skills or expertise or training in that myself. So I would not see myself as being necessarily able to do that. (Richard, October 13, 2005)

Finding 9: The lecturers' experience in science communication was variable. Those with extensive science communication experience were more likely to include civic science training in their teaching practice.

4.5 Science Communicators' Views of Science Communication Training for Biotechnologists

To provide an external perspective of the science communication training that undergraduate biotechnology students receive, the seven science communicators and three science communication lecturers were asked to comment on their views of the science communication training that biotechnologists currently receive as part of their degree programs. They were not asked to comment specifically on the degree program in the case study. These participants were also asked to describe their experience in teaching science communication to determine if their viewpoints came from a perspective informed from experience (Table 7).

Six of the seven science communicators did not feel sufficiently qualified to comment about the level of training that biotechnologists receive in science communication as they had no involvement in the undergraduate or postgraduate training of biotechnologists. Only Erin, a science communicator with prior tertiary science teaching experience, provided a response to this question. Erin, who described the science communication training she embeds in her nanoscience lectures as "informal" indicated she felt the level of training provided to biotechnologists, and science students more generally, was "insufficient" (November 28, 2005).

Table 7

Description of Science Communicators' Current Employment

Science Communicator	Position
Chloe	Biotechnology Project Officer
Jane	Manager Science Communication Business
Sarah	Community Relations Officer
Oliver	Science Education Officer
Nicky	Science Education Officer
Erin	Nanotechnology Lecturer
Wendy	Science Outreach Project Officer

When the science communication lecturers, Tess, Charles and Cate, were asked to comment on the level of science communication training that science students receive at the tertiary level, all responded to the question. Tess indicated she felt biotechnologists learn how to "spin" their science to interested audiences rather than engage in dialogue (October 18, 2005). Cate and Charles's comments concurred with Erin's (science communicator) view that the level of science communication training provided to undergraduate science students is insufficient. Cate felt the level of training provided to molecular biologists was particularly "below standard" and indicated that she feels science lecturers often believe that making their students give an oral presentation is all that is required for communication training (October 27, 2005). Similar to the response of Linda (early-career biotechnologist), Cate emphasised that the requirement for an undergraduate student to give an oral presentation alone does not constitute science communication training. Cate also indicated that the lack of critical evaluation of these presentations made it very difficult for the students to build on their communication skills:

> A lot of the lecturers in those areas will tell you that they do it in their own units anyway. You know, they'll tell you 'Well, we do, you know, our students learn how to give a talk'. They have to give a talk but they never give them any feedback. They don't train them how to give a talk, give the talk, then get feedback and then give them another go...That's not really training people, improving their skills just because they have to do it. They might be horrible at it but – and then no one ever tells them how they could do better. So, you know, I think it's – my guess is, but it's just a guess, is that their communication training for biotechnologists is below standard. (Cate, October 27, 2005)

Finding 10: Science communication lecturers believe the level of science communication training provided to biotechnologists is insufficient.

4.6 Conclusions

Overall, the results presented in this chapter suggest that the current state of science communication training for the tertiary biotechnology students in the case study is limited. Very few of the students expressed the view that their undergraduate or postgraduate biotechnology degree program provided them with any form of science communication training, let alone training in how to engage audiences broader than their peers. In addition, very few of the students were aware of the communication skills training available to them. While the undergraduate biotechnology students are able to enrol in a unit in science communication specifically designed to generate an understanding and appreciation of the importance of public engagement, none of the students surveyed had completed this unit, very few indicated an interest in enrolling in this unit, and many were unaware the unit is offered by the university. At the postgraduate level, while the students are offered generic communication skills training, none of the doctoral students surveyed had completed the training course, none planned to enrol in the course, and very few expressed the view that the course would improve their science communication skills.

The biotechnology doctoral students' and early-career biotechnologists' perception of a lack of science communication training within the program appears to be accurate given the lecturers' responses to questions about their provision of this training. Very few of the lecturers were able to identify where in the biotechnology program the students are taught communication skills beyond the provision of report writing skills. None could identify where the students are taught skills in public engagement, only a minority were aware the university offers a unit in science communication, and very few promoted the unit as a possible elective unit for the biotechnology students to complete as part of their degree program.

The apparent absence of any form of formal science communication training for these biotechnology students suggests these students may not graduate from their program and enter the workplace as competent civic scientists, that is, able to demonstrate a clear understanding of why science communication is important, well equipped to communicate both the technical and social and ethical aspects of their research, and aware of how scientist-to-scientist communication and public engagement should be approached. The results of this section of the case study suggest the opposite – the undergraduate students have a limited understanding of science communication and public engagement, half of the early-career biotechnologists do not feel well equipped to communicate their research, and very few of the doctoral students and early-career biotechnologists report communicating their research beyond their scientific peer group.

5. STAKEHOLDER VIEWS OF SCIENCE COMMUNICATION

The following chapter addresses Research Question 2 and explores how the stakeholder' views of science communication may impact on the provision of civic science training for undergraduate and postgraduate students in the biotechnology program. In this chapter the stakeholders' views of the communication of biotechnology and biotechnologists' role in communicating with non-scientists are examined. Biotechnologists' awareness of the approaches they can, and should, take to science communication is also explored.

To establish the importance of science communication to the stakeholders in the case study, the second year undergraduate biotechnology students, early-career biotechnologists and lecturers were asked to give their views of various aspects of science communication. In the questionnaire, the undergraduate students were asked for their views of what science communication should aim for, and how important they rate the role of biotechnologists in public engagement. In their interviews, the early-career biotechnologists and lecturers were asked for their views on public engagement and how successfully they feel biotechnology has been communicated with non-scientists. As access to the doctoral students was limited in this study, these students were not asked any questions relating to this section of results.

Interview data was also obtained from the science communicators and science communication lecturers to gain an external perspective of the importance of science communication. In addition to the questions asked of the early-career biotechnologists and lecturers, the science communicators and science communication lecturers were also asked a series of questions about biotechnologists' awareness of science communication best practice.

The data generated in response to these questions is presented in the following section. In contrast to the previous section, the data for the early-career biotechnologists and lecturers have been combined as these groups were asked identical questions. Any notable differences between the views of the participants in

these groups have been highlighted. Similarly, the data generated from the science communicators and science communication lecturers have been combined under a single heading.

5.1 Undergraduates' Views of Science Communication

In the questionnaire, the 23 second year undergraduate biotechnology students were asked a number of questions about their views of science communication and biotechnologists' role in communicating with non-scientists. It was recognised that the students could potentially have minimal understanding of science communication, so the students were asked to mark their responses on adjacent rating scales. This would enable the students to indicate how they value specific items in comparison to others. For example, rather than asking the students to comment on the public understanding of science, the first of these continuous rating scale questions asked the students to rank two items (i) how important they feel it is that non-scientists understand the technical aspects of biotechnology, and (ii) how important they feel it is that non-scientists understand the social and ethical implications of biotechnology.

In response to this first rating scale question, most of the undergraduate students surveyed (n=18) indicated that they felt both items were important by providing rating scores of five or over. When these two items were compared, it was found that the students ranked the "understanding of the social and ethical implications of biotechnology research" significantly higher in importance than the 'understanding of the technical aspects of biotechnology research' (Z=2.798; p=0.005). When the reasoning behind these responses were explored in the follow-up interviews, three of the students interviewed indicated they felt the communication of technical details with non-scientists was less important than communication of the social and ethical implications because non-scientists may find the technical details of research too difficult to comprehend. For example, when asked why he rated the technical item

lower than the social and ethical item, Sam said "It would just go straight over their head what you are talking about" (February 2, 2006).

The undergraduate biotechnology students were also asked in the questionnaire to rate the success of a science communication activity according to four possible outcomes (improved awareness, understanding, debate or acceptance of biotechnology products and processes by non-scientists). According to these students' rating scale responses, they do not draw any distinction of success based on these outcomes ($H=2.381$; $df=3$; $p=0.4905$). In the follow-up interviews, however, there was a clear indication that the most successful outcome of science communication was the improved acceptance of biotechnology. Six of the seven students interviewed stated this directly or indirectly by linking acceptance with the outcome they rated as most successful. For example, two students linked the improved understanding of biotechnology with improved acceptance. Jessica stated "I think they need to understand the social and ethical, so that we understand it, they understand it and they allow us to do our work" (November 14, 2001). Nadine said "Acceptance, I think, sort of shows more that they have understood and they are happy to go with it." (November 14, 2001).

Finding 11: The majority of the undergraduate biotechnology students indicated that it was important for non-scientists to understand the technical, social and ethical details of research. The rationale for this improved understanding was most commonly an increased acceptance of biotechnology.

As well as acknowledging a role for science communication in improving non-scientists understanding of research, the undergraduate students also acknowledged the importance of biotechnologists taking an active role in communicating their research (Figure 5). When asked to rate the importance of biotechnologists, science communicators, government, journalists and campaigning groups in communicating the (i) technical aspects and of biotechnology research to non-scientists, and (ii) the social and ethical implications of biotechnology research to non-scientists, biotechnologists were included within the most important groups for communicating

both (H=46.217; df=4; p<0.0001 for the former, H=21.883; df=4; p=0.0002 for the latter). Science communicators were also given the highest rating for communicating biotechnology research.

The second year undergraduate biotechnology students were also asked in the questionnaire to indicate who the intended audience for science communication efforts should be. With the exception of journalists, the students ranked the public as significantly less important targets for communication than the other groups listed (Figure 6; H=62.959, df=5; p<0.0001). The follow-up interviews indicated that the students saw communication with scientists, government and the biotechnology industry as an essential part of a scientist's job, as opposed to communication with non-scientists and journalists which was seen as an "optional extra". Jim indicated he would only communicate with the public if approached by an "interested" individual.

> Well, I think it is important to communicate to other people in the field but I really don't think it's for the public unless they are interested......I think it would depend on whether the non-scientists were really interested. So I actually wouldn't say that they had to go out and actively tell them. The onus is not on them to go out and tell people what they are doing. I mean why would they do that? (Jim, November 14, 2001)

Over half the students interviewed (n=7) indicated they would restrict communication with journalists because they felt they were biased and would not accurately represent their views. Emma stated:

> Journalists really don't know that much about biotechnology and they also would put their beliefs into what they write which is not right for it. They have their own opinions that might or might not be correct. And people tend to believe what they write because they are journalists. (Emma, November 14, 2001)

Finding 12: The undergraduate biotechnology students see scientists and science communicators as playing an important role in communicating science, but rate the public and media as the least important groups to engage with.

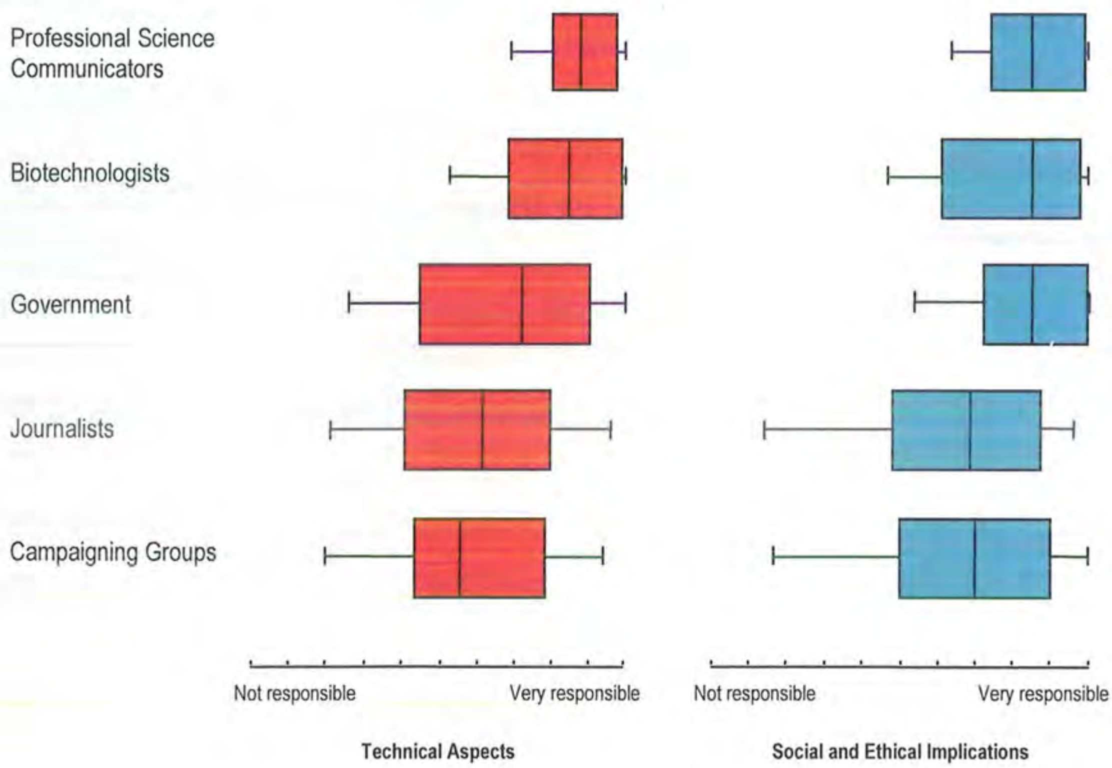

Figure 5: Second year undergraduate biotechnology student (n=23) responses to the questions "How responsible should the following groups be for communicating the technical aspects of biotechnology research to non-scientists" (red box plots) and "How responsible should the following groups be for communicating the social and ethical implications of biotechnology research to non-scientists" (blue box plots). The items are arranged in the order of importance attributed to the technical research item.

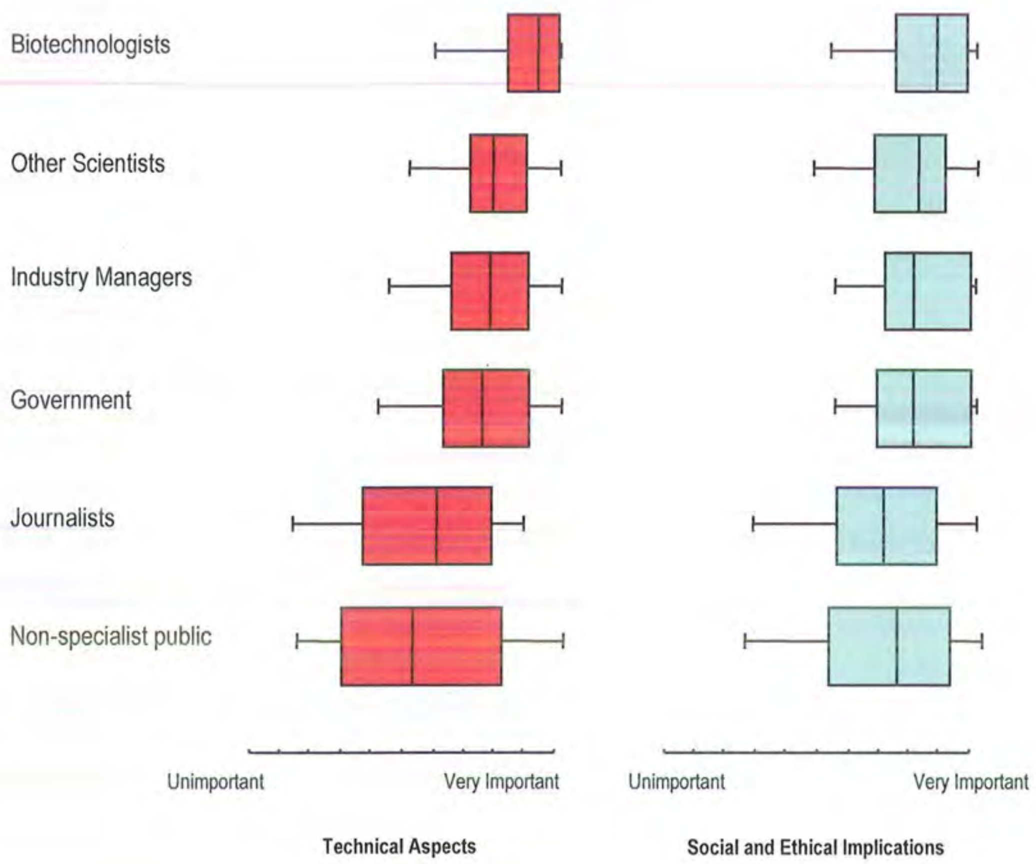

Figure 6: Second year undergraduate biotechnology student (n=23) responses to the questions "How would you rate the importance of communicating the technical aspects of biotechnology research to the following groups?" (red box plots) and "How would you rate the importance of communicating the social and ethical implications of biotechnology research to the following groups?" (blue box plots). The items are arranged in the order of importance attributed to the technical research item.

5.2 Early-career Biotechnologists' and Lecturers' Views of Science Communication

In their interviews, the early-career biotechnologists and lecturers were asked for their views on how biotechnology has been communicated and the role that biotechnologists should play in science communication. If the participants indicated they felt biotechnologists did have a role to play in public engagement, they were then asked to elaborate on whether they felt this role extended to communication about the social and ethical implications of research or should be limited to the communication of the technical aspects of research. This group was also asked if they felt all biotechnologists should be involved in public engagement activities, including those in the early stages of their career.

5.2.1 Communication of Biotechnology with Non-Scientists

When asked how successfully they thought biotechnology had been communicated with non-scientists, five of the six early-career biotechnologists, and eight of the 10 lecturers indicated that they felt biotechnology, on the whole, has been poorly communicated. The remainder of the individuals in these two groups indicated they felt that the communication of biotechnology to non-scientists had been variable, with some areas communicated more successfully than others. None of the early-career biotechnologists or lecturers expressed the view that the communication of biotechnology could be considered an overall success.

There was a clear indication from a number of the early-career biotechnologists and lecturers that the lack of successful communication of biotechnology with non-scientists was intimately linked, in their view, to the complexity of the discipline. Three of the lecturers spoke of the "difficult concepts", "complex issues" and "complexity" associated with biotechnology. Pierce (lecturer) indicated he felt part of the difficulty in communicating biotechnology lies in defining exactly what biotechnology is:

> I think people have difficulty getting their head around what biotechnology actually means. And maybe that's because it's a multi-disciplinary sort of science. It also has the commercial aspects, the commerce aspects of marketing and management embedded in it as well. And so I think even the students that come into biotechnology are often unclear as to what biotechnology actually is. And so when the scientists themselves – or the younger biotechnologists we train to be biotechnologists – are not sure what a biotechnologist is, it's then quite difficult to then communicate that to people who are non-scientists. (Pierce, October 17, 2005)

Five other participants (1 lecturer, 2 early-career biotechnologists, 1 science communicator) in the study at various points in their interviews also indicated that the communication of biotechnology has been inhibited by the difficulty in defining biotechnology. Abbey (lecturer) stated "What is biotechnology? Its different things to different people" (October 20, 2005). Anne-Marie (early-career biotechnologist) also elaborated on the difficulties in defining biotechnology:

> I had a couple of students last year try and define biotechnology. There were that many different definitions. So if we can't get it straight how can others? (Anne-Marie, November 22, 2005)

Erin (science communicator) indicated that biotechnology was often confused with genetic modification. She stated "probably 90% of the population have heard the word biotechnology before" but suggested many think biotechnology is synonymous with genetically modified foods (November 28, 2005). Natalie (early-career biotechnologist) expressed a similar view to Erin:

> This is one of the things that kind of annoys me about the term *biotech*, because everyone thinks about modification and DNA and things. But what I do is biotech but no one would think that, you know. I think the general public wouldn't think it was biotech because it doesn't really involve DNA-based research. (Natalie, February 16, 2006)

Two early-career biotechnologists and one lecturer (Natalie, Matthew and Richard) spoke of biotechnology communication being dominated by the "spin" generated by biotechnology companies. Natalie (early-career biotechnologist) indicated she felt biotechnology communication had been "PR driven" (February 16, 2006). Matthew (early-career biotechnologist) and Richard (lecturer) stated:

> I still see there's a fair bit of spin put on things. And I think for quite a few lay people, biotechnology is a very singular sort of item. It's either stem cell research and its bad or its GM culture and it's bad. We don't seem to be able to give people a more broad view of things, balanced arguments as to benefits. (Matthew, February 20, 2006)

> It's quite a complex issue because there's many drivers in there. One of the strong drivers in biotechnology is the commercial side. So the biotechnology companies, even in their communication will necessarily going to put a spin on, and flavour it their way. And likewise the active groups that are sort of anti-biotechnology – all the different levels – will spin the message their way and there's not a lot of science being communicated. There is lots of myths and legends and non-science. (Richard, October 13, 2005)

Richard's description of biotechnology communication as "myths and legends" (October 13, 2005) was a theme that was raised by eight other participants in the study. Four lecturers, two early-career biotechnologists, and three science communicators at various stages in their interviews described biotechnology as being "miscommunicated", "misconceived", "misinterpreted", and "misunderstood". There was a clear indication from three participants that the public did not know the "truth". Hamish (lecturer) stated "the general community's perception of science is so often removed from reality" (October 20, 2005). Matthew (early-career biotechnologist) thought biotechnology could benefit from "clearing away all the shadowy ideas that people have about science" (February 20, 2006). James (lecturer) felt lecturers should "tell the students the truth about science" (October 17, 2005).

Finding 13: The majority of early-career biotechnologists and lecturers expressed the view that biotechnology has been poorly communicated, in part as a result of difficulties in defining biotechnology.

The early-career biotechnologists and lecturers were also asked in their interviews if they felt biotechnologists have a role to play in the communication of biotechnology to non-scientists. All agreed that biotechnologists have a role to play in public engagement, but disagreed on whether this role should be mandatory or not. Three of the ten lecturers felt this role should be compulsory for all biotechnologists, including Alan (lecturer) who felt science communication should be mandatory because "science is nothing unless it's communicated" (December 9, 2005). Later in his interview he expanded on this theme:

> If you're a scientist, if you don't communicate with other scientists you're a waste of space because no one ever knows what you know, whether you've done published papers, you don't give – you don't talk to anyone, you may be absolutely brilliant but you exist in a vacuum, you're on your own. And to a certain degree that applies to the community – that science does things and the community out there needs to know and hopefully support what they do. (Alan, December 9, 2005)

In contrast, the majority of the lecturers (n=7) and all of the early-career biotechnologists expressed the view that all biotechnologists should not be required to engage with the public. While they agreed that the biotechnology profession as a whole needed to be represented in some capacity by biotechnologists, they indicated that individual biotechnologists should be able to refuse to participate in science communication activities. They indicated scientists who are not comfortable with communicating, or unskilled in communication, should not be "forced" to engage with non-scientists, instead they should be able to "play to their strengths" and remain in their laboratories doing research. Gareth (lecturer) described this as choosing "horses for courses" (October 20, 2005). Linda (early-career

biotechnologist) stated "I think there are scientists who probably aren't good at it, and so yeah, it's fine for them to stick to the lab rat mould". Abbey (lecturer) stated:

> Some of them will by nature be not good at that. It would be better to allow the good communicators to represent the science - still being scientists - and those who aren't, keep them doing what they're good at. People should work to their strengths. (Abbey, October 20, 2005)

Three interviewees (one lecturer and two early-career biotechnologists) even suggested that biotechnologists who are not skilled in communicating may present more problems than solutions. They indicated that the involvement of unskilled communicators may be "problematic" (Matthew, early-career biotechnologist, February 20, 2006) and result in "more problems, more confusion" (Anne-Marie, early-career biotechnologist, November 22, 2005). Gareth (lecturer) indicated that he felt biotechnology industry had made a "mistake" in allowing biotechnologists to communicate with non-scientists, and indicated it would always be preferable to use science communicators as an intermediary between scientists and non-scientists when communicating biotechnology:

> I think that a mistake again that the biotech industry made is that they didn't get those sort of specialist communicators. They got scientists to do it which is not a good idea because scientists just get passionate about the science, not about the communication. And they expect everyone else to, you know, see the same vision that they see. And it doesn't work like that so you need someone who knows something about science but is a specialist communicator. And not everyone can do that. (Gareth, October 20, 2005)

Three others (one lecturer and two early-career biotechnologists) also indicated that the involvement of a science communicator in the science communication process may be beneficial, and at the very least biotechnologists' role in communicating with non-scientists should involve working with a science communicator as an intermediary between them and non-scientists.

Gareth's portrait of researchers as passionate, focused and disconnected individuals was a theme that emerged throughout the interviews with four other individuals from this group. Owen (lecturer) described some scientists as "nerdy type people that get involved in some tunnel of their scientific expertise" (December 14, 2005). David (lecturer) indicated "they don't like to do anything that takes them out from what they're focused on" (February 16, 2006). Linda (early-career biotechnologist), as indicated in her previous quote, described laboratory based scientists as "lab rats" and Anne-Marie (early-career biotechnologist) stated "It's like the brilliant scientists who can do the research, but when you get them to speak to someone you really can't understand what they're talking about" (November 22, 2005).

Finding 14: All early-career biotechnologists and lecturers agree that biotechnologists have a role to play in public engagement, but their views varied on whether civic science should be compulsory for all biotechnologists. The majority indicated that biotechnologists should be able to refuse to participate in science communication activities. Some indicated that professional science communicators should be involved, and others expressed the view that scientists' involvement could be problematic if the wrong scientist was chosen to represent the profession.

As well as being asked to comment on whether they felt biotechnologists had a role to play in the communication of biotechnology research with non-scientists, the early-career biotechnologists and lecturers were also asked if they felt biotechnologists had a role to play in the communication of the social and ethical implications of biotechnology with non-scientists. Most of the interviewees (n=13), with the exception of one lecturer and two early-career biotechnologists, indicated that they felt biotechnologists have a responsibility to be involved in this form of public engagement.

The reasons provided for why biotechnologists should involve themselves in communicating about the social and ethical implications of their research were varied. One interviewee (Hamish, lecturer) saw the social and ethical implications of research as an integral component of research that should not be separated from the

technical details of research at any stage of research, including discussion of research and its outcomes. Two others (James and Alan, both lecturers) indicated that the communication of the social and ethical implications of research was particularly important in biotechnology because of the potential the discipline has to impact on the community. Alan stated:

> I think scientists should in whatever they do, whatever area they are, try to understand the social and ethical implications of what they do and ramifications. And, I guess, if there's a failing within science education overall it is that the system for quite some time - and particularly I think the Australian system quite historically - has bred technocrats rather than scientists. And so they don't spend a lot of time thinking about philosophy, ethics and all those areas...... In biotechnology it's somewhat more important than potentially in some other areas is because of its greater potential impact on the social, ethical, health, the whole gang – it's a thing that's focussed very much on affecting human lives. (Alan, December 9, 2005)

Another interviewee (Pierce, lecturer) felt communicating with non-scientists about the social and ethical implications of biotechnology allows the technical details of research to be contextualised and therefore better understood:

> I think it has to be both and I think that's perhaps the best way to capture people's imagination about biotechnology. If you just present it as some sort of arcane new technology or whatever, I think it turns a lot of people off but if they can see the relevance of it to, you know, social things, to, you know, their particular lifestyle – how is it going to affect me – then it makes it more real. (Pierce, October 17, 2005)

In contrast to the majority who indicated that biotechnologists have a responsibility to communicate the social and ethical implications of their research, three interviewees (one lecturer and two early-career biotechnologists) indicated they felt biotechnologists should restrict their communication with non-scientists to technical

details. The lecturer John, felt biotechnologists' role in communication should involve a "very clinical" report of the technical details, and political, ethical and social debate should be left to others. He stated "I don't think it's the biotechnologists' job to do" (October 13, 2005). Rosie, one of the early-career biotechnologists opposed to biotechnologists' role in science communication also stated "I probably wouldn't say the biotechnologist is totally responsible but they do have a certain level of responsibility to, you know, inform the public and to reassure them that we're not playing God in that sense" (February 28, 2006).

Finding 15: The majority of the early-career biotechnologist and lecturers indicated that biotechnologists should be involved in communicating with non-scientists about the social and ethical implications of their research. Many felt this aspect of communication should not be separated from the technical aspects of research.

The early-career biotechnologists and lecturers were also asked to comment on whether or not they felt early-career biotechnologists have a role to play in the communication of biotechnology with non-scientists early in their careers. Fourteen of the sixteen interviewees indicated that early-career biotechnologists have a contribution to make to science communication. Richard (lecturer) felt that early-career biotechnologists in particular, should be encouraged to take on this role because they were "closer to the community" than more senior biotechnologists (October 13, 2005). Three lecturers felt they may need to take on this role if required to represent their laboratory or if they were in a position of leadership. Two of the more senior lecturers (Alan and Hamish) felt there may be issues with credibility, but each of these interviewees acknowledged that there was a trade-off between credibility and being seen as partisan. Alan stated:

> Somebody late in their career, you know, Professor this or head of that, can also be seen as being partisan for that area. Whereas an early-career one doesn't belong to anyone yet so there's a balance between that. Yes, obviously there's a greater authority and greater knowledge of people further on in their career and they obviously would carry greater weight for

politicians, et cetera. That's where that credibility is important. But on a one-to-one sort of basis at the community level it may be actually the younger ones who have indirectly more credibility or less baggage – that's a balance between the two. (Alan, December 9, 2005)

The two interviewees who did not feel early-career biotechnologists have a role to play in communicating with non-scientists, Mary and Anne-Marie, were early-career biotechnologists themselves. Mary felt this form of communication should be left to more "advanced" biotechnologists (February 28, 2006). Anne-Marie felt early-career biotechnologists are too inexperienced to communicate. She stated "the junior scientist needs to learn their craft before they can communicate it accurately" (November 22, 2005).

Finding 16: The majority of the early-career biotechnologist and lecturers indicated that early-career biotechnologists should be involved in science communication. Two lecturers felt the perception of these early-career scientists as more partisan would counterbalance any perception of them as being too inexperienced and underqualified to represent the profession, although two early-career biotechnologists felt this would not be the case and public engagement would be better undertaken by more senior scientists.

5.2.2 Biotechnologists' Efforts in Communicating with Non-scientists

The early-career biotechnologists and lecturers were also asked if biotechnologists need to improve the way they communicate their research, and if they indicated yes, they were then asked to suggest how these improvements could be made. All of the interviewees agreed communication between biotechnologists and non-scientists needs to improve. Only four individuals (two lecturers and two early-career biotechnologists) however, were able to suggest how these improvements could be made. Richard, a lecturer with little science communication experience, indicated he felt communication could be improved simply by increasing the level of

biotechnologists' participation. In direct contrast to this, Abbey, a lecturer with significant experience in science communication, indicated she felt simply increasing biotechnologists' participation would not be sufficient. She felt biotechnologists need to improve both the frequency of their civic science activities and their science communication skills.

Half of the lecturers and two of the early-career biotechnologists indicated they felt the communication of biotechnology could be improved. They indicated that non-scientists should be better informed about biotechnology, non-scientists' understanding of biotechnology should be increased, and public misconceptions about biotechnology should be rectified. Rosie (early-career biotechnologist) stated "The more correct information there is out there, the better" (February 28, 2006).

Two of the most senior lecturers, David and Alan, both with significant research portfolios, indicated they felt biotechnologists needed to improve their science communication efforts for the benefit of the discipline. They felt improving public engagement would lead to better funding of biotechnology research:

> They have to improve both [communication of the technical aspects of research and the social and ethical implications] to get support for their field further on in life. But also, you know, to justify how the money is spent and there's more accountability for everything so you can't just take the money and do the work like a hobby. You've really got to explain now why you think it's important, what you think you've achieved and what the benefits are. (David, February 16, 2006)

> In this case it's kind of self serving – we've got to go and get the boys on our side so we get more money. Well, in very much the same way we've got to get the community on side to gain more resources… I do believe an informed audience is always the better one than an uninformed one. (Alan, December 9, 2005)

Finding 17: All of the early-career biotechnologists and lecturers agreed communication between biotechnologists' and non-scientists needs to improve. The most commonly suggested area for improvement was increased public understanding and awareness of science.

5.3 Science Communicators' and Science Communication Lecturers' Views of Science Communication

The science communicators and science communication lecturers were asked the same questions about the communication of biotechnology as the early-career biotechnologists and lecturers. They were asked in their interviews if they felt biotechnology had been communicated successfully, whether biotechnologists have a role to play in the communication of biotechnology to non-scientists, if this role should extend to communication about the social and ethical implications of research, whether early-career biotechnologists should be involved, and if and how biotechnologists can improve their science communication efforts. This group was also asked a series of additional questions about how biotechnologists should approach science communication.

5.3.1 Communication of Biotechnology with Non-scientists

Like the early-career biotechnologists and lecturers, this group of participants all agreed that the communication of biotechnology could not be considered an overall success. Two of the science communication lecturers were highly critical of the way biotechnology has been communicated with non-scientists. Cate stated that she felt biotechnology had been communicated "appallingly" (October 27, 2005) and Charles stated that "science has got this terribly, terribly wrong" (November 11, 2005).

Tess (science communication lecturer) and two other science communicators felt public engagement in this area had been poor overall, and the remaining five science

communicators felt that some areas of biotechnology had been communicated successfully and others had not. Linda (science communicator) stated "It's a bit hard to gauge really – it depends on what you're talking about" (November 22, 2005). Chloe (science communicator) indicated she felt biotechnology had been promoted very well to those "that want to hear" about biotechnology, but felt communication about biotechnology has suffered from a lack of "balanced" perspective (December 12, 2005).

Throughout the interviews and across the participant groups the perception that accessing balanced information about biotechnology is difficult, was noted in the responses of five other individuals from various participant groups (three lecturers, one science communicator and one early-career biotechnologist). Matthew (early-career biotechnologist) indicated he felt biotechnology was either seen as "stem cell research and its bad or its GM culture and its bad" (February 20, 2006). He felt people were not given a "broad view" of biotechnology. Abbey (lecturer) felt the press coverage of biotechnology had reached the point where the science content "almost has to be a freak show for it to get into the headlines" (October 20, 2005). Richard (lecturer), as previously quoted, felt that science communication had been lost in the battle between biotechnology companies and anti-biotechnology lobby groups. Owen (lecturer) and Erin (science communicator) stated:

> I think it's polarised. It is the good biotech and the bad biotech. It's not well balanced. The public would have typically 'Yes, we need this, this is going to save cancer problems, AIDS and whatever' or they say 'This is going to kill us; this is genetically modified bugs'. And I would find it rare that someone has a balanced view. (Owen, lecturer, December 14, 2005)

> There have been a lot of interested parties who've communicated biased messages ....and I think that's probably the fault of the scientists that in some ways the biotechnology community let the interested parties... dominate the debate. And, still to this day, I really don't think I can recall a single biotechnologist who has come out and concertedly made an effort to say 'Hang

on, let's look at this from a balanced perspective' (Erin, science communicator, November 28, 2005)

Finding 18: All science communicators and science communication lecturers expressed the view that biotechnology has been communicated badly. The science communication lecturers were particularly critical of science communication overall in this area. Six interviewees indicated that the public find it difficult to obtain balanced information about biotechnology due to the predominance of biased information provided by biotechnology lobby groups.

Unlike the early-career biotechnologists and lecturers, the majority of this group (eight of the ten) indicated that they felt every biotechnologist should play a direct role in communicating their research with non-scientists. Erin (science communicator) felt they should communicate "whether they want to or not" (November 28, 2005). Jane (science communicator) indicated she felt all scientists had a responsibility to communicate:

> I think we all have to re-conceive of this idea that, that only some people are communicators in this. Because actually everybody is, everybody is...The idea that they're not is ridiculous. We've got to get our heads around that. (Jane, November 15, 2005)

Sarah, science communicator and community relations manager for a university, stated:

> I think most scientists very much live in a silo where they're working on their research.....They might know the work within their research group and they don't sort of think beyond that, but there are lots of opportunities out there for scientists to engage in the public debate if they have the confidence to, and also share their, share their work with at least people within, you know, within their research community, at least kind of keep their name out there. They don't have to be kind of constantly out there spruiking their research

like salesmen, but they do have to have - they do have a responsibility for, particularly if they're publicly funded, they have a responsibility to share that stuff. (Sarah, November 4, 2005)

The remainder, while agreeing that biotechnologists as a whole should be involved in communicating the technical details of research with non-scientists, felt individual biotechnologists should be given the right to refuse to participate in science communication activities. Chloe (science communicator) indicated she felt biotechnologists should be allowed to focus on their strengths and only communicate if they are disposed to. She felt that biotechnologists should not be any more responsible for the communication of their work than any other professional group:

> Why is it that we have this need for science communication but we don't have this need for political communication or accounts communication or legal communication, like why don't we have those people out there who actually translate the other facets to our lives that some of us are oblivious to know about? So, I don't feel there's a humungous need for biotechnologists to actually go and learn communication themselves. I think people have strengths and I think they should focus on their strengths. If their strength happens to be communication that's a great asset and you can certainly facilitate everyone else, but I don't see why they need to be all rounders. Other professionals aren't all rounders. (Chloe, December 12, 2005)

Cate (science communication lecturer) indicated that she felt that a mandated science communication role for every biotechnologist was not necessary, and the choice to pursue a laboratory role exclusively is legitimate provided these researchers do not inhibit the communication of science by their peers who choose to communicate their research:

> I think that there are some who are just very traditional and old school in their approach and ivory towerish and, you know, 'We should just get on with our work and the public should just trust us because'. And they don't even think

> about it. They just think, you know, 'We know what we're doing, we're trained. Let us just get on with our work'. And that's probably the best approach for funding some scientists. Let them just get on with their work. There are some people who have no big picture of where science fits in society. They're just – they might be excellent researchers and they might, you know, do some great things but just, you know, let them be on the peripheral, just get on with their work. Fair enough. As long as they're not an impediment to how science does fit into society and, you know, as long as they're not in a position where they can block, I think, the really critical role for science communication to happen. You know, they might not be a good ambassador or a good communicator and that's fine because everyone isn't going to be. (Cate, October 27, 2005)

Two science communicators also agreed with the three early-career biotechnologists and lecturers who indicated they felt that biotechnologists who are not skilled in communicating may present more problems than solutions. Erin described the difficulties involved in science communication when the biotechnologist involved is a poor communicator and recommended that "Everyone should have the opportunity to do what they want - so if you've got somebody who wants to do that, provide them the skills and experience. But don't let a rogue trader loose" (November 28, 2005). Sarah felt there is an inherent danger in allowing all biotechnologists to communicate as some may "overstep the boundaries of where their research is" (November 4, 2005). She felt it would be preferable to use science communicators as an intermediary between scientists and non-scientists when communicating biotechnology with non-scientists.

Finding 19: The majority of the science communicators and science communication lecturers indicated that all biotechnologists should be involved in science communication, but recognised their varying capacity and interest in civic science.

The theme of researchers as passionate, focused and disconnected individuals was as evident in this group of participants as it was in the early-career biotechnologist and

lecturer group. Four of the science communicators and one science communication lecturer made statements expressing this view. Chloe (science communicator) spoke of researchers as being legitimately disinterested in science communication as a result of their "laser-like focus" on research (December 12, 2005). Oliver (science communicator) spoke of scientists becoming more "isolated" the longer they were in the profession (October 25, 2005), and Sarah (science communicator) stated "I think most scientists very much live in a silo where they're working on their research....They might know the work within their research group but they don't sort of think beyond that" (November 4, 2005). Erin (science communicator) stated "I don't think scientists in the whole are very well rounded" (November 28, 2005). She later stated "I mean, I work in a research centre where the CEO, managing director, is quite articulate and very, you know, well versed on the social and technical and policy and, you know, the whole, good rounded picture. But if I was a marketing manager or a person in authority I would be concerned if he spoke to the press". Cate (science communication lecturer) while acknowledging that her views are a gross generalisation, nevertheless described scientists as too busy with their research to spend time "thinking about the moral and ethical implications of their own research" (October 27, 2005).

Finding 20: Ten of the 26 interviewees (three lecturers, two early-career biotechnologists, four science communicators and one science communication lecturer) described researchers as passionate, focused and disconnected individuals. This was cited as a reason for why not all scientists may want to engage with the public and why civic science may not be suited to all scientists.

In direct contrast to the early-career biotechnologists and lecturers who indicated the involvement of a science communicator in the science communication process may be beneficial, three of the science communicators (Jane, Oliver and Nicky) indicated they felt the direct involvement of all biotechnologists in science communication was the best option. A number of drawbacks in using intermediary science communicators were identified, the most predominant objection being the lack of trust in the communicator. Jane and Oliver stated:

> I think there's real value in talking to the real deal. People don't want to deal with an intermediary. They want to – we need a human face to it. We need to understand that there are real people doing real research. The danger with a lot of these things, when there's decisions to be made, is that people abdicate the responsibility. They see it to some sort of nameless faceless kind of person. And I think it's really important for people's own perception of their responsibility – whether it's on water or whether it's on whether we use antibacterial soap or whether it's on biotech – that we see other real people as being responsible. We don't – if it's a nameless faceless bureaucracy - we don't tend to then go well, they're responsible, so am I. But if it's a real person then I think that's important. (Jane, November 15, 2005)

> And I think the public really want to hear straight from the horse's mouth. If you have too many intermediaries in there, there's the real danger that it becomes, that the public perceives it to have been spin doctored. Whereas if they can actually hear it – you know, what scientists understand and believe - and hear the passion, I think, that some of the scientists have, is really important. (Oliver, October 25, 2005)

Finding 21: Three science communicators were all able to identify reasons why the direct involvement of all biotechnologists in science communication is important and why the replacement of scientists with science communicators can be problematic in public engagement.

As well as asking the science communicators and science communication lecturers to comment on whether they felt biotechnologists had a role to play in the communication of biotechnology research with non-scientists, the participants were also asked if they feel biotechnologists have a role to play in the communication of the social and ethical implications of biotechnology with non-scientists. As with the early-career biotechnologists and lecturers, all of the science communicators and

science communication lecturers indicated that they felt biotechnologists have a responsibility to be involved in this form of communication.

The reasons provided for why biotechnologists should involve themselves in communicating about the social and ethical implications of their research were varied. Wendy (science communicator) agreed with lecturer Mike, that the social and ethical implications of research are integral components of research that should not be separated from the technical details at any stage. The most common reason given, however, for supporting biotechnologists' involvement in communicating the social and ethical implications of their research with non-scientists was that it would provide the biotechnologists with an opportunity to reflect on, and acknowledge, their own practice. This view was most prevalent in the group of science communicators and science communication lecturers, with five commenting on the benefit of self-reflection inherent in communicating the social and ethical issues related to biotechnology. But this theme also emerged in the responses of the science communication lecturers, and participants from other groups (one lecturer and one early-career biotechnologist). This self reflection was described as a "reality check" (Owen, lecturer, December 14, 2005) that enabled researchers to question the rationale behind their choice of research project. It was also stated that participation in the communication of the social and ethical issues related to biotechnology could enable biotechnologists to "identify the social and ethical issues" and thereby maintain contact with society (Erin, science communicator, November 28, 2005), to involve themselves in ethical decision-making (Wendy, science communicator), and to "acknowledge the responsibility of their work" (Chloe, science communicator, December 12, 2005).

In addition, Natalie (early-career biotechnologist) and Cate (science communication lecturer) felt biotechnologists could benefit from participating in science communication by enabling the scientists to reflect on the direction of their research, including its moral and ethical dimensions:

> They should give themselves pause and they should actually have a think about whether or not it is research that they should be doing. I mean, most people are going to go 'OK, I've considered the issues and of course I think I should still do it'. But I think there should be moments of pause for everyone. (Natalie, February 16, 2006)

> My personal belief is that there should be scientists in the moral and ethical debates because what we as scientists need to think about is 'What are the implications of our research?' Because we can control to a certain extent how we spend our time and we can say 'I don't want to work on that, I want to work on this other thing because I can see that this will lead to something really – or had the potential to- lead to something really positive'. So we need to be thinking about the implications of our own work – absolutely... We need to think a lot more strategically and science communication helps scientists to do that better. (Cate, October 27, 2005)

Charles (science communication lecturer) felt that biotechnologists need to acknowledge that they are technical experts when discussing the technical details of their research, but also need to acknowledge when they communicate the social and ethical implications of their research they present this information as informed citizens, not as an experts in social and ethical issues:

> I think the scientists saying 'our expertise is in the science and that's where it stops'.....I mean that clearly is nonsense. They have to be accountable. ....They certainly should be saying 'We are the technical experts....but I'm also a citizen, you know, and I see the implications'. (Charles, November 11, 2005)

Finding 22: All of the science communicators and science communication lecturers expressed the view that biotechnologists should be involved in communicating about the social and ethical implications of their research. Many indicated that scientists

could benefit from civic science by enabling them to better reflect on their practice as scientists.

The redefining of science to include a civic science role was another theme that emerged in the interviews of a wide range of participants; three science communicators, one science communication lecturer, and two lecturers. Oliver (science communicator) commented on the change required in science and Charles (science communication lecturer) expanded later in his interview on his views of the civic science role required of scientists:

> I think the main, the main thing which would make a difference is allowing the scientists to see the value in communicating to a wide audience, to a wide range of audiences and see that it's actually an integral part of their job, that it's not something you do just to raise your profile or not something you do to, you know, to win Brownie points within your organisation, that it's actually – it helps science. (Oliver, October 25, 2005)

> It's got to be seen not just as something you do if you have the time or if someone has the interest. It's got to be seen as an integral part. I think the problem is with scientists and policymakers is that they have a very narrow view of innovation. They see the process as one of producing x, y or z. It might be a new vaccine. It might be a new genetically modified food. What they have got to understand is that people in the community have the right, and do, reject these things if they think there's a problem. So innovation – a key part of innovation – is explaining what you do to the community before the innovation hits the community.....So what I'm saying is policymakers and scientists need to rethink the innovation process. (Charles, November 11, 2005)

Three participants (Erin, Wendy and Abbey) indicated the need for this civic science role to be reflected in teaching. Abbey (lecturer) said "Whatever we do in our lives we should be able to share it with others and be part of the community" (October 20, 2005). Erin (science communicator) and Wendy (science communicator) stated:

> I think we need a fundamental change in the paradigm which exists in tertiary education away from building researchers into building scientists - a much broader sense, looking at where they're likely to go and what skills they're likely to need and I think, you know, particularly in areas like biotechnology where, you know, the granting issue comes up or your external funding comes up much quicker than say in physics, there is a need to ensure that it is a continuing thread. It is a skill development in exactly the same way that lab extraction techniques or lab techniques is a pervasive theme across all the years. (Erin, November 28, 2005)

> I think every science student should be taught to be a science communicator, because these days students graduate thinking they're going to be in a research laboratory and they're going do fantastic things and write journal articles. But they don't stop to think about what else they could be doing to let other people know. And that's always forgotten, even at the undergrad level. But I think if you can instil that sort of communication training for students in their undergrad years, they'll grow up to be scientists who say I want people to know about what I'm doing. (Wendy, December 5, 2005)

Alan (lecturer) indicated he felt a "failing" of the training of science students was the exclusion of civic science training within the program.

Finding 23: Six individuals from various participant groups indicated that civic science should be seen as an integral part of the practice of science and this should be reflected in training by the inclusion of civic science within the tertiary biotechnology curriculum.

The science communicators and science communication lecturers were also asked to comment on whether or not they felt early-career biotechnologists had a role to play in the communication of biotechnology with non-scientists. Every interviewee agreed that these scientists have a contribution to make to science communication. Like

Richard (lecturer) who felt early-career biotechnologists, in particular, should be encouraged to take on this role because they were "closer to the community" (October 13, 2005), two of the science communicators felt early-career biotechnologists (in comparison to more senior biotechnologists) are seen as less "isolated" (Nicky, October 25, 2005), and not "focused exclusively on science" (Charles, November 11, 2005).

Finding 24: All science communicators and science communication lecturers indicated they feel early-career biotechnologists have a role to play in the communication of biotechnology with non-scientists.

5.3.2 Biotechnologists' Efforts in Communicating with Non-scientists

The science communicators and science communication lecturers were also asked if biotechnologists need to improve the way they communicate their research. All of the interviewees agreed communication between biotechnologists' and non-scientists needs to improve. In contrast to the lecturers and early-career biotechnologists, all except one of the interviewees were able to provide suggestions as to how biotechnologists could improve their communication. Wendy (science communicator), like Richard (lecturer), felt communication could be improved simply by increasing biotechnologists' role in the communication process. Wendy felt science communication could only improve if "communicating science can be part of every researcher's job" (December 5, 2005).

Four of the science communicators, like Abbey (lecturer), indicated they felt improving the quality of communication was required rather than simply increasing biotechnologists' participation. There was a clear indication from three of the science communicators that this could only be achieved by biotechnologists redressing their deficit views of science communication and entering into negotiation with non-scientists about biotechnology research. Oliver (science communicator) stated: "From what I've seen and heard and read, scientists often don't consider what that

reaction will be" (October 25, 2005). Jane (science communicator) indicated she felt a better appreciation and understanding of the complexity of the communication process is required:

> We think we've got to listen to them as well but it's much more than that. It's actually a network communication. Human communication doesn't work in two dimensions. It works in three and, for all we know, four. And how we see things and the judgements we form do not happen just in that channel based on what you said to them and what they said to you. It's so informed by other things as well. And so if we go into these things saying 'I've got this argument' and 'I've got this argument', 'I want to get this point across' and 'maybe we might do that', then I think we're missing out on understanding that there's all this stuff coming in from around the sides. And we're not allowing for enough understanding of how people's world views and how people's judgements of what is good and what's right is influenced by that stuff around the side and the stuff behind them. (Jane, November 15, 2005)

Charles (science communication lecturer) indicated he felt biotechnologists' communication role needs to extend from "selling science" to the community to making dialogue and negotiation about research an integral part of the innovation process:

> The radical shift that I would like to see is scientists, science undergraduates, scientists and technologists seeing innovation in its broader definition. Which is, the community is actually a part of the process. The community isn't an add-on at the end.... Get them involved in the process all along the way, not produce a genetically modified food and say 'Why don't you accept this?' and then be surprised when they reject it. (Charles, November 11, 2005)

In contrast to the predominant view of the lecturers and early-career biotechnologists, only one science communicator indicated they felt communication

could be improved by ensuring that non-scientists are better informed about biotechnology.

Finding 25: All of the science communicators and science communication lecturers expressed the view that communication between biotechnologists' and non-scientists needs to improve. Suggestions for ways in which communication could improve included improving scientists' levels of participation in public engagement activities and changing their current approach to science communication.

5.3.4 Biotechnologists' Approach to Science Communication

The science communicators, who are often the intermediaries in the communication between scientists and non-scientists, were also asked to comment on whether they felt biotechnologists, and early-career biotechnologists in particular, are aware of the approaches they should take to science communication programs or activities. Science communication lecturers, who could potentially provide scientists with the skills and knowledge required to participate in science communication programs and activities, were also asked this question.

One science communicator and two science communication lecturers were adamant that biotechnologists are not aware of the approach they should take to communicating with non-scientists. Of the ten science communicators interviewed, these three (Sarah, Cate and Charles) reported having the most experience in interacting with biotechnologists for science communication purposes. Cate suggested many scientists follow a deficit approach to science communication:

> I'll elaborate on that one because I think that's a really critical point. I think a lot of biotech – a lot of biotechnologists, a lot of scientists in general have a – they, they really follow the deficit model, you know, the deficit model of science communication that if we only explain to people what we're doing and tell them what we're trying to do then they will understand and they will

accept it, and so they have insufficient awareness of what effective communication models are and so they tend to slip into this well, we'll just explain what we're on about and everyone will be happy, so it's a real education model, deficit model. (Cate, October 27, 2005)

Charles indicated that science communication activities are not seen as ' *real science*:

> I think they [biotechnologists] don't see it as a high status, high level activity. It doesn't bring many rewards so why do it? In fact, I wouldn't be surprised if some regard it as a demeaning activity almost. A real scientist – like real men don't eat quiche – real scientists don't communicate with the unwashed. (Charles, November 11, 2005)

Cate also indicated in her answer to this question that there was a perception that scientists involved in science communication were not seen as being "real scientists" (October 27, 2005). Four of the science communicators with science backgrounds also commented on the little value given to science communication activities and the perception that these activities are not real science. Sarah (science communicator) felt that communicating scientists "tend to be treated with disdain by their peers quite often and left out to dry" (November 4, 2005). Erin (science communicator) reflected this sentiment in her interview when she stated:

> I see this across a lot of sciences. There's this real [feeling], you know, the social and ethical side of things – that's not real science... Whether it's a fear of questioning or inspection, I'm not sure. But, you know, if you're seen to be not a pure researcher...then you're seen as less of a scientist than those who are involved in it. (Erin, November 28, 2005)

Natalie (early-career biotechnologist) and John (lecturer) also commented on the perception that science communication is not seen as *real science*. Natalie felt that her science communication activities were detrimental to her science career, stating

"I don't really use any (scientific) language a lot of the time anymore....I think in some ways I might come across as patronising when I talk to other scientists" (February 16, 2006). John stated: "People just don't see the importance of it....The system says you need to do traditional hard core science didactic learning and there's no room for this fluffy stuff involved in talking with other people" (November 4, 2005).

Of the eight science communicators and science communication lecturers to answer the question that explored whether they thought early-career biotechnologists, in particular, were equipped to communicate, six indicated they thought the skill levels in this group were variable. They described early-career biotechnologists' efforts in communicating their research with non-scientists as "sporadic", "scattered", "hit and miss", and "erratic". Chloe (science communicator) felt in comparison to the older generation, early-career biotechnologists seemed more able to communicate. Yet Sarah (science communicator) felt that early-career biotechnologists expressed a "certain amount of arrogance about not needing to communicate" (November 4, 2005). Erin (science communicator) thought they were very aware of the benefits of communicating with their peers, but at the same time, inculcated with the belief that communicating with non-scientists (particularly the media) could be detrimental to their career. She stated "I think in university cultures there's almost, at the departmental level, a pervasive belief that you shouldn't talk to the media. You know, you risk becoming a pariah because – oh my God – you might say something wrong" (Erin, November 28, 2005).

Finding 26: Three of the science communicators and science communication lecturers expressed the view that biotechnologists are not aware of the approaches they should take to science communication programs or activities. Those with most interaction with biotechnologists for science communication purposes expressed these views the strongest, suggesting that science communication is marginalised because it is not seen as a science in itself.

Four of the science communicators indicated that they had not had enough interaction with biotechnologists to comment on biotechnologists' awareness of science communication. Based on her experience as a scientist and in teaching science students and professional biotechnologists, Tess (science communication lecturer) stated:

> I think they're also unaware of the literature that is criticising them [biotechnologists]. And they're very, very quick to say it's rubbish if it criticizes this. I went to a genetically modified foods workshop, I did the workshop, a whole day seminar. And it seemed to me that as soon as anybody said anything that was critical, they immediately said 'Oh, they didn't know what they were talking about'. So that sense of knocking the ground from underneath the criticiser's feet. So the only people allowed to speak on this are those who've got the biotechnology background. They were disregarding expertise in the area of environment. So it was as if the only expertise that was allowable was their own expertise and that's lack of self awareness. That's lack of knowing the literature on science and it would be exactly the same if you put chemists in there. It's not a criticism of biotechnologists as such – it's a criticism of all scientists, that they don't – we aren't - critical of our own image. (Tess, October 31, 2005)

The remaining two science communicators felt that barriers to the effective communication with non-scientists by biotechnologists did not lie in a lack of awareness of how to approach science communication, but in other areas. Wendy (science communicator) indicated that she felt that the primary question faced by scientists with regard to science communication "hasn't really been about where to start. It's more about whether to do it or not" (December 5, 2005).

In Chloe's (science communicator) experience it is often commercialisation issues that prevent biotechnologists from communicating effectively:

> With biotechnology what I've found is that the world of science is, you know, it's all about publishing. You've got to get yourself in a paper, that's a mark of how good you are - is how many papers you've been published in and how many credible ones as well. And with biotechnology, because it's seen as the commercialising arm of science, or at least biological science, it's such an issue with promoting your work because there's patent infringement and stuff like that and so they're more likely to publish rather than patent and everyone, like especially in the business area, at the department, we're trying to go no, patent, don't publish but see how that – we're then lacking in that communication because there's now a one year lag. (Chloe, December 12, 2005)

Commercialisation issues representing a barrier to science communication was a theme that emerged in two other interviews. Rebecca (doctoral student) indicated in her interview that she had no involvement in science communication because of commercial arrangements with the group funding her doctoral research. Similarly, Matthew (early-career biotechnologist) indicated that he had little involvement in science communication because the company he was involved in research with "didn't want me communicating with any scientist whatsoever", let alone non-scientists (February 20, 2006).

Finding 27: Commercialisation was seen as a barrier to scientists' participation in science communication by three participants from various stakeholder groups.

Those science communicators and science communication lecturers that agreed that early-career biotechnologists have a role to play in science communication were also asked to comment on how important they feel science communication skills are for early-career biotechnologists. All agreed these skills were very important for early-career biotechnologists. Erin (science communicator) felt these skills would be essential for early-career biotechnologists to ensure they were able to secure employment and research funding. She stated "If you can't talk to me about what you're doing or talk to the researchers or the people providing the funding – who are

invariably marketing people or non technical people – you're in trouble" (November 28, 2005). Sarah (science communicator) felt providing early-career biotechnologists with science communication skills was important but this needed to be combined with the opportunity to practice these skills.

Charles (science communication lecturer) and Jane (science communicator) also agreed they felt communication skills were important for early-career biotechnologists, but more importantly felt biotechnologists should be aware of the rationale behind communicating with non-scientists, rather than being provided with a science communication tool kit.

> That sort of level is technically based. In other words it's about how can I improve my communication? That's important – what I call nuts and bolts – but the nuts and bolts has to be put into some sort of context. In other words, we need to understand why are we doing this? What's the point. Why do we want to communicate with people? And they need to understand it's not just a matter of communicating to, it's also listening. What are the community concerns? Are they real concerns? Are they perceived concerns? And whichever they are they need to be tackled. (Charles, November 11, 2005)

> I think if we focus on adding on the skills it's kind of like doing a band-aid kind of thing. We'll add this on and we'll stick that on to you. But unless we've got the underlying understandings right about, you know, how knowledge informs a society and shapes those social forces and then, you know, how it works, then I think all we're going to be doing is keeping on adding on and trying to teach new skills and things all the time, rather than actually integrating it into the culture of how we pursue and use knowledge, which – I still hope that that's what it's about. (Jane, November 15, 2005)

Finding 28: All science communicators and science communication lecturers agreed that science communication skills are essential for early-career biotechnologists. Two also stated that these early-career biotechnologists needed an underlying

awareness and understanding of the rationale behind public engagement in addition to communication skills.

5.4 Conclusions

Overall, the results presented in this chapter which relate to Research Question 2 indicate that most of the participants in the case study, from all of the stakeholder groups, agree that biotechnologists have a role to play in public engagement. However, the stakeholder groups vary with regard to their views of the relative importance, nature and scope of this activity. The undergraduate students' acknowledge how important it is that non-scientists understand biotechnology but do not rate public engagement as an important form of communication for scientists. The early-career biotechnologists and lecturers were more likely to see using science communicators as a buffer between scientists and the public as advantageous. The science communicators and science communication lecturers were more able to identify the drawbacks of scientists not engaging with the public directly.

There were also varying views expressed about whether or not there should be boundaries placed on the type of engagement that biotechnologists undertake with non-scientists. The lecturers and early-career biotechnologists were more likely to feel that making compulsory science communication for biotechnologists would be unreasonable. In contrast, the majority of science communicators and science communication lecturers supported a mandated role for scientists in public engagement. Many of the science communicators also indicated that biotechnologists are not sufficiently aware of the approaches they should take to public engagement and could benefit from science communication training. A number felt this training should not be limited to teaching communication skills, but should focus instead on the understanding of what science communication is and why it is important, in combination with an opportunity to practice communication skills.

6. STAKEHOLDER VIEWS OF SCIENCE COMMUNICATION TRAINING

The following chapter addresses Research Question 3 which explores the participants' views of science communication training at the tertiary level. In this chapter, the level of importance assigned to science communication training is examined. The stakeholders' views of science communication training, how this should be delivered, and the barriers and supports for delivering science communication training within the biotechnology degree program, are also explored.

To establish the value the stakeholders in this case study attribute to science communication training and its possible inclusion within the biotechnology program, the students, early-career biotechnologists and lecturers were asked to describe their views of science communication training. The first, second and third year biotechnology students in the case were asked to rate the importance they attribute to science communication training in relation to other components of their program. This question was also asked of a large number of other first, second and third year undergraduate science students. The doctoral students were asked to comment on how important they feel science communication training is in their postgraduate program, and the early-career biotechnologists and lecturers were asked for their views on science communication training as part of the undergraduate education of biotechnology students.

The doctoral students, lecturers and early-career biotechnologists were also asked a series of questions examining whether these participants feel the inclusion of science communication training within the biotechnology program is warranted. They were asked to comment on whether they felt training in this area could impact on an individuals' ability to improve their communication. They were asked to indicate if the generic communication skills training provided to the students according to the university's graduate attributes program is sufficient science communication training, and whether or not training in scientist-to-scientist communication is substantially different from the training required for public engagement.

Interview data were also obtained from the science communicators and science communication lecturers to gain an external perspective of the importance of science communication training. These participants were asked the same questions as outlined above for the early-career biotechnologists and lecturers.

6.1 Undergraduate Students' Rating of Relative Importance of Science Communication Training within their Curriculum

The main focus of the shortened questionnaire was the question 'How important do you think it is that the following items are included in your undergraduate biotechnology degree program?' The students were asked to rate 12 curriculum items listed underneath this question.

In total, 343 questionnaires were administered and collected from the undergraduate students (Table 8). Fifty two of these students were administered the extended questionnaire, the remainder were administered the short questionnaire. Sixty nine of these students were enrolled in the biotechnology program. The remaining 274 students were enrolled in the following programs: biomedical science (n=50), molecular biology (n=66), forensic biology (n=10), environmental science (n=4), veterinary science (n=47), biological science (n=43), marine biology (n=8), conservation biology (n=36), or other degree program (n=10). These 274 students were combined into one category labelled 'non-biotechnology programs'.

Both of these questionnaires contained the question which asked the students to rate the importance of 12 curriculum items in their degree program. Analysis of this rating scale question indicated there were no statistically significant differences in the mean scores of the students enrolled in the biotechnology program compared with the students enrolled in the non-biotechnology programs (see Figure 7), with the exception of two items, *Technical skills* ($Z=-2.844$, $p=0.0045$) and *An awareness of the public's perception of the risks associated with research and research outcomes* ($Z=-2.085$, $p=0.0371$). *Skills in communicating research with non-scientists* was

rated as one of the lowest four items by students in both the biotechnology program and the students in the combined non-biotechnology programs.

Table 8

Undergraduate Students Administered the Short Questionnaire by Program of Enrolment

Year of enrolment	Biotechnology Program *n*	Non-Biotechnology Programs *n*	Total *n*
1st Year	17	219	236
Female	6	153	
Male	11	66	
2nd Year	23	29	52
Female	9	24	
Male	14	5	
3rd Year	29	26	55
Female	13	19	
Male	16	7	
Total	69	274	343

Finding 29: There was no significant difference between biotechnology undergraduate students rating of the importance of science communication within their degree program and the views of the undergraduate students enrolled in other science degree programs. The students rated scientist-to-scientist science communication high in relative importance compared to other components of their programs, and communication with non-scientists as relatively low in importance.

All subsequent analyses were performed using only the data obtained from the first (n=17), second (n=23) and third year (n=29) biotechnology students. When the mean scores of the biotechnology program year groups were compared there was no statistically significant differences in scores for eight of the twelve items, including the items *Skills in communicating research with other scientists* and *Skills in communicating research with non-scientists* (Figure 8). Significant differences were observed for the items *A broad knowledge of general scientific facts and theories* (H=6.116, p=0.047), *Data analysis skills* (H=6.864, p=0.0323), *An awareness of the public's perception of the risks associated with research and research outcomes* (H=6.623, p=0.0365), and *Business and marketing skills* (H= 8.859, p=0.0119).

There were no significant differences in the mean scores for seven of the listed items for the biotechnology students according to sex, including the items *Skills in communicating research with other scientists* and *Skills in communicating research with non-scientists* (Figure 9). Post hoc analyses indicated that three items were rated significantly higher in importance by the females: *An understanding of human ethics regulations and related issues, An understanding of animal ethics regulations and related issues,* and *An awareness of the public perception of risk associated with research.* Differences in the responses between these groups were highest for the two items *An understanding of human ethics regulations and related issues* (Z=-3.953, p<0.0001) and *An understanding of animal ethics regulations and related issues* (Z=-4.6, p<0.0001).

Finding 30: There was no significant difference between biotechnology undergraduate students rating of the importance of science communication skills training within their degree program according to year of enrolment or sex. Irrespective of stage of progression through their program and their gender, the biotechnology students rated scientist-to-scientist communication skills high in relative importance compared to other components of their programs, and communication with non-scientists as relatively low in importance.

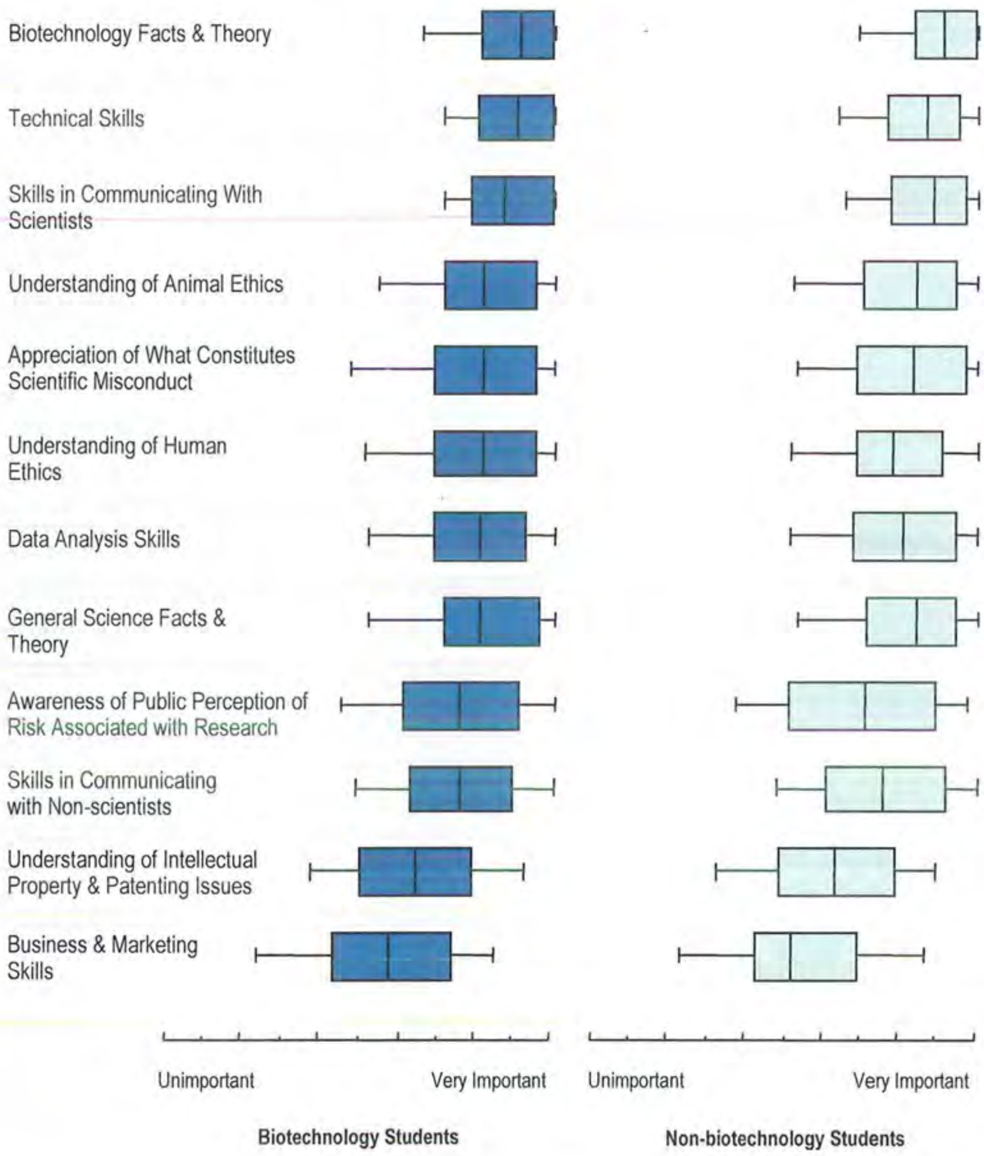

Figure 7: Undergraduate science student ranking of the importance of 12 curriculum items according to degree program of enrolment. The biotechnology students' (n=69) responses to the question *How important do you think it is that the following items are included in the undergraduate biotechnology curriculum?* are represented by the dark blue box plots. The responses of the science students' (n=274) enrolled in non-biotechnology degree programs are represented by the light blue box plots. The items are arranged in the order of importance attributed by the biotechnology students.

Figure 8: Undergraduate biotechnology students' ranking of the importance of 12 curriculum items, according to year group. The first year students' (n=17) responses to the question *How important do you think it is that the following items are included in the undergraduate biotechnology curriculum?* are represented by the light red box plots. The second year students' (n=23) responses are represented by the medium red box plots. The third year students' (n=29) responses are represented by the dark red box plots. The items are arranged in the order of importance attributed by the first year students.

Figure 9: Undergraduate biotechnology students' ranking of the importance of 12 curriculum items according to sex. The female biotechnology students' (n=28) responses to the question *How important do you think it is that the following items are included in the undergraduate biotechnology curriculum?* are represented by the red box plots. The male biotechnology students' (n=41) responses are represented by the orange box plots. The items are arranged in the order of importance attributed by the female students.

When the data for the biotechnology students in each year group were combined, the distribution of the curriculum items fall into four significantly different categories according to the level of importance attributed to them by the students ($H=392.123$, $df=11$, $p<0.0001$; Figure 10). Post hoc analyses indicated the students ranked *Technical skills* and *Knowledge about biotechnology* and *Communication between scientists* as the most important components of their curriculum (median scores of 9.2 to 8.8). Significantly lower importance was attributed to the second category of items which included *Broad science knowledge, Data analysis*, and the items related to misconduct and ethical issues (median scores of 8.3 to 8.1). The third category of items, included *Skills in Communicating research with non-scientists* and *An awareness of the public perception of risk* (median scores of 7.6 and 7.7, respectively). And the fourth category, *Intellectual property* and *Business and marketing skills*, were rated significantly lower than all other items listed (median scores of 6.45 and 5.75, respectively).

The focus of the present doctoral study is science communication and civic science, and in this particular question, the relative ranking of the items *Skills in Communicating research with non-scientists* and *Skills in communicating research with other scientists*, in relation to other items in the biotechnology curriculum. As such, the ranking of the items other than these two science communication related items are not explored further in either this chapter or the discussion. It is notable, however, that the results obtained in the ranking of these non-communication related items is consistent with the a study of Schibeci and coworkers (Schibeci, Barns, Kennealy, & Davidson, 1997) who found that biotechnology students showed most interest in scientific issues, some interest in ethics, and little interest in marketing issues.

Finding 31: The combined results of all three years of biotechnology students indicates that the students' ranking of the relative importance of the 12 curriculum items listed fell into four tiers. The more traditional skills taught in science degrees were included in the top two tiers of importance by the students, with the communication of science between peers included in the top tier. Public engagement

items, including the communication of science with non-scientists, was included in the third tier. And the fourth tier, the items rated least important, were related to the commercialisation of science.

In the follow-up interviews, 13 second year biotechnology students were asked to explain their response to the two science communication items. All of the students interviewed indicated they felt *Skills in communicating with research with other scientists* was an essential skill for biotechnologists to have, and rated this item as one of the top three most important items for inclusion within their program. In contrast, *Skills in communicating research with non-scientists* was ranked as one of the lowest four items on their list by the majority of the students interviewed (n=11). These students provided a number of reasons as to why they attributed this civic science item a relatively low priority. Four students indicated that communicating with non-scientists was not important because an understanding of science was only important for scientists (n=1) and biotechnology may be too difficult for the public to understand (n=3). One student indicated he ranked science communication as one of the lowest of his responses because he felt that communication with non-scientists was only required when the public were "interested":

> Well, I think it is important to communicate to other people in the field but I really don't think it's for public unless they are interested. (Jaxon, February 27, 2006).

Two of the students gave the *Communication with non-scientists* item a relatively low level of importance because they felt science communication skills would be best offered as specialised course, rather than an integral component of the biotechnology degree program. Elena stated "Because that [skills in communicating research with non-scientists] is probably what you want to be basing a science communication course on" (February 27, 2006). Joel stated "I think if that [skills in communicating research with non-scientists] is something you want to go into then you'll take a minor or a double degree in that. I don't think that is particularly important" (February 27, 2006).

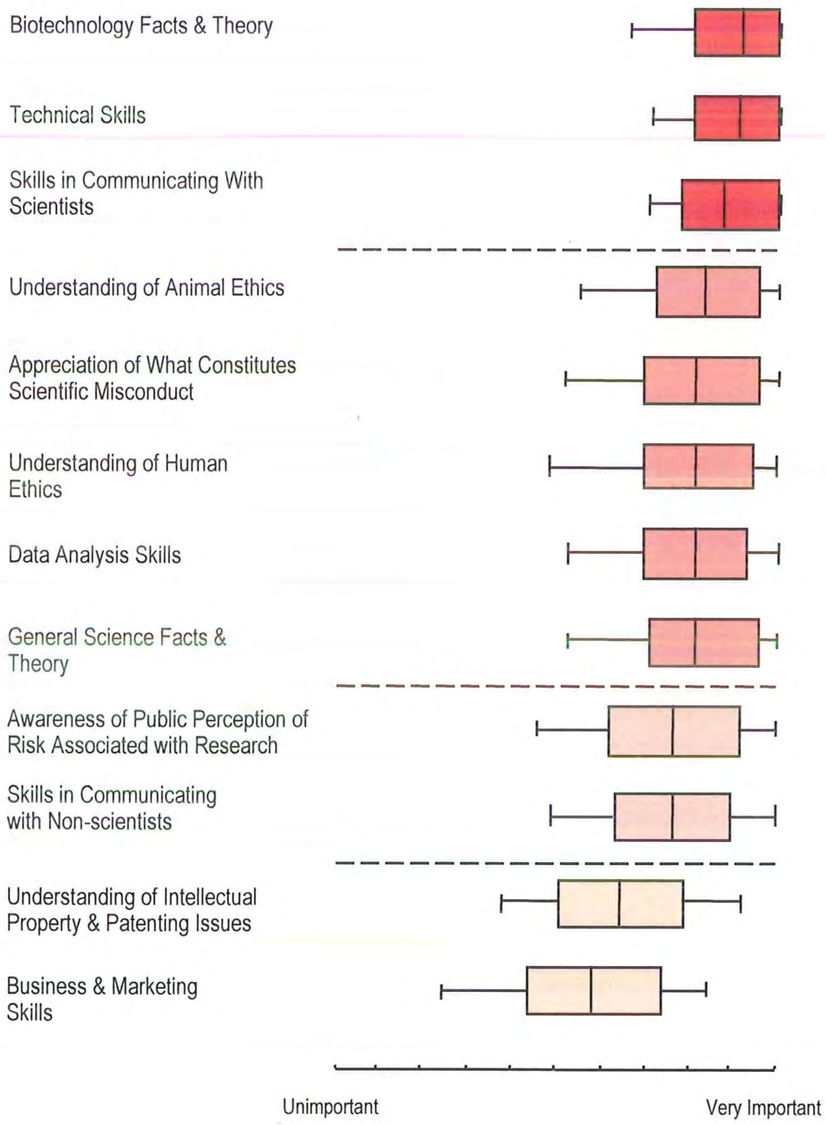

Figure 10: Undergraduate biotechnology students' (n=69) ranking of the importance of 12 curriculum items listed in the question *How important do you think it is that the following items are included in the undergraduate biotechnology curriculum?* The items are arranged in the order of importance attributed by the students. Adjacent items that have significantly different mean scores are separated by a dashed line.

The two students who did indicate that they felt skills in communicating research with non-scientists was a very important inclusion in their biotechnology degree program rated all of the items highly. When one of these students was prompted to indicate which item they would leave out if one were to be removed from their program of study she selected the *Skills in communicating with non-scientists* item.

Finding 32: The second year biotechnology students interviewed indicated they felt scientist-to-scientist communication skills is an essential for biotechnologists, as opposed to public engagement skills which are a relatively low priority. This item was ranked low for a number of reasons including the perception of low levels of interest or understanding by the public and the belief that these science communication skills would be better offered to science students wishing to specialise in this area.

6.2 Doctoral Students' Views of Science Communication Training

The doctoral biotechnology students were asked in their interviews to comment on the importance of science communication training within the postgraduate program. They were asked specifically about the level of importance they attribute to the generic communication skills training course offered to them, how much time they had available to attend the course, and whether or not they thought the course should be compulsory.

Four of the six doctoral students that answered this question felt the generic communication skills training course was not relevant for them because they already had the requisite generic communication skills that are taught in this course. Danny also felt the course would be too generic and not science-specific enough. He stated "I'm not too sure how beneficial it would be. I've been to some sort of, some types of things before and they tell you sort of generic things. But you never really come out of it knowing 'How do I deal with it in my situation?'" (Danny, November 12, 2001).

Of the two doctoral students who felt the course was important, one was an international student (Georgie) who felt communication training would be particularly beneficial for students experiencing difficulties associated with the English language. The other, Rebecca, while indicating she thought the course would be useful, felt she would not attend the generic skills communication courses offered because she had insufficient time available to attend:

> Definitely time constraints are always a major issue. I mean, if you were allocated time to go and do these courses then yeah, fine. But if you had to make it up out of your research time or your own time then I think a lot of people would not really consider it. (Rebecca, November 14, 2001)

When each of the doctoral students were asked if they felt the course should be compulsory, there was a mixed response. Four students indicated they would not support compulsory communication training, two were undecided and one agreed it should be compulsory. Rebecca, opposed to the idea of compulsory science communication training, stated:

> I don't think any of these kind of development skills should be compulsory at the postgrad level. I mean, it should be encouraged and I do know of examples of people who definitely need to do some...I wouldn't agree with it being compulsory. You've got enough to do with your research as it is and a lot of these skills you do pick up on the way. (Rebecca, November 14, 2001)

Finding 33: The majority of the doctoral biotechnology students indicated that attending the generic communication skills training offered by the university would not be beneficial and none had enrolled. Only one doctoral student felt the generic communication skills course should be compulsory. Another felt she had insufficient time to attend.

6.3 Early-career Biotechnologists' Views of Science Communication Training

The early-career biotechnologists were asked in the interviews for their views on the science communication training of tertiary biotechnology students. All except one of the interviewees, Anne-Marie, felt science communication should be a component of tertiary science education. Anne-Marie did not support the provision of compulsory science communication training at this level as she felt not all scientists are suited to science communication, not all should be expected to communicate, and therefore not all scientists should be forced into science communication training. Like a number of the undergraduate biotechnology students interviewed, she felt science communication training would be better offered as specialist training to students with a specific interest in becoming science communicators.

Of the five interviewees who agreed science communication should be a part of undergraduate and/or postgraduate biotechnology training, two felt undergraduate biotechnology students would be unlikely to share their views of the value of this form of training. Rosie stated "I see that there will be benefits even though, even if they may not" February 28, 2006). Natalie expanded on this:

> They think they're being forced to do it, and they don't think it is relevant....So, but their focus I think would definitely be 'OK, I've enrolled in a science degree. Science is what I want to do. Yep, technical skills, let's go. But get me a job'. (Natalie, February 16, 2006).

Natalie felt the provision of science communication training for tertiary science students should continue throughout their careers through the provision of professional development in this area by their employees. She stated she felt science communication "should be part of their professional development with that organisation" (February 16, 2006).

Finding 34: The majority of the early-career biotechnologists indicated that science communication training should be included within the tertiary biotechnology

curriculum. Two early-career biotechnologists felt, however, that few of the undergraduate students would appreciate the value of this training. One also felt this training should be supported with continuing professional development in the workplace.

The early-career biotechnologists were asked in their interviews if they felt the provision of science communication training for biotechnology students could improve the student's ability to communicate. The majority (n=5) indicated they felt the provision of this form of training could improve, to some degree, the science communication skills of every individual participating. The early-career biotechnologists were also asked if the skills required for science communication with non-scientists are significantly different from those required for communicating with fellow scientists. Two early-career biotechnologists spoke of similarities between the two forms of communication: the requirement for information presented in context, clarity, the correct level of information, and an awareness of the audiences' understanding and knowledge of the science to be discussed. But the remainder felt there were significant differences between the two. For example Linda, a forensic biotechnologist, stated:

> You have to have a completely different mindset. If you're communicating with other scientists, which is what you find when you go to a conference as compared to when you go to a careers expo at a uni or something, the level of detail that you go into. And, I mean, you just have to be so conscious when you're talking to a non-scientist of what they're going to read into what you say. And that's, yeah, again something I think - because I'm not necessarily a research scientist – I've probably got a better understanding of how normal people would read into things because I'm not a boffin – lab rat. (Linda, November 22, 2005)

Finding 35: The majority of the early-career biotechnologists indicated that the provision of training could improve the science communication skills of all scientists.

Communication between scientists was seen as requiring a significantly different skill set than the skills required for public engagement.

6.4 Lecturers' Views of Science Communication Training

In their interviews the lecturers were asked a series of questions aimed at identifying their ideal view of science communication training for biotechnology students, and whether they felt this form of training could be introduced into the biotechnology program. The lecturers were asked specifically if they felt science communication training should be a component of the undergraduate education of biotechnology students. They were also asked to identify supports and barriers to the provision of this training within the biotechnology program, and the likelihood of its inclusion. They were then asked to identify the possible benefits arising from the improved science communication training of students within the program.

In addition, the lecturers were asked to answer a series of questions aimed at examining whether they felt the current state of the biotechnology curriculum provided biotechnology students with the skills required for public engagement. They were asked to provide their views on whether they feel scientist-to-scientist communication differs from the form of communication that occurs between scientists and the public.

6.4.1 Inclusion of Science Communication within the Biotechnology Program

The majority of the lecturers (n=9) indicated they supported the provision of science communication training for biotechnology students, with most (n=8) indicating this form of training should be embedded within existing units of the biotechnology program. There was acknowledgement, however, by two of the lecturers that

tracking and maintaining the delivery of science communication training within the degree program could be difficult if attempts were made to embed this material within existing units. John felt science communication training could potentially "fall through the cracks" if attempts were made to deliver it in a number of different units (November 4, 2005). Only one lecturer felt the material would ideally be delivered as a stand-alone unit.

Gareth, who did not support the provision of this form of training at the undergraduate level, suggested that students with an interest in science communication could take up postgraduate studies in science communication. He also felt that communicating with non-scientists was not a role that scientists should assume without specialist training, and stated:

> A mistake again that the biotech industry made, is that they didn't do that – is that they didn't get those sort of specialist communicators. They got scientists to do it, which is not a good idea because scientists just get passionate about the science, not about the communication. And they expect everyone else to, you know, see the way, the same vision that they see. And it doesn't work like that. So you need someone who knows (a) something about the science but, (b) is a specialist communicator. And not everyone can do that. (Gareth, October 20, 2005)

Finding 36: The majority of biotechnology lecturers supported the provision of science communication training within the biotechnology curriculum, ideally embedded within existing units of study. Half of the lecturers, however, indicated inclusion of new material would be problematic. One lecturer felt this material would be better delivered as specialist postgraduate training in science communication.

6.5.2 Supports and Barriers to the Provision of Science Communication Training

Seven of the ten lecturers were not aware of any specific supports provided for the provision of science communication training of biotechnology students. Three of the lecturers felt the teaching and learning department in the university could offer them support for the provision of science communication training if they required it, but none had sought help of this nature from the department. When asked about the barriers to the provision for science communication training, however, the lecturers were very specific about what they felt the barriers were. The inability to find room for science communication in an already crowded biotechnology curriculum and a predicted lack of interest in science communication by biotechnology students were the two most prevalent answers provided by the lecturers.

David (lecturer), who felt the science communication training could ideally be delivered in a stand-alone unit, indicated he felt the program was so crowded it would be unlikely that room would be made for a compulsory unit of this nature. Another four lecturers also indicated that making room for this form of training in existing units would be problematic. These lecturers included Pierce, the program chair, and Gareth, the lecturer who felt there was no place for science communication in the undergraduate biotechnology program. They stated:

> Having just gone through a whole review of the biotechnology program and we never put it in there, obviously I thought - and we thought as a committee - that it wasn't as high a priority as something else. And I think the difficulty with biotech is that it is so darn broad that the difficulty is deciding what to leave out, rather than what to put in. And so science communication probably gets pushed further down the heap because of that. (Pierce, October 17, 2005)

> There's a lot of skills that are missing from the biotech degree which I would put ahead – things like quantitative skills..... I mean, there's a lot of, as I say, quantitative skills, problem-solving skills, knowledge-based subject and

things like that which they really need to get. So communication – if you were to put it on the list - would come down, down a bit. (Gareth, October 20, 2005)

Some lecturers also indicated that other areas not currently in the biotechnology curriculum would be given higher priority for inclusion than science communication. One felt science communication training could possibly extend the degree completion time of the biotechnology students and therefore would not be considered for inclusion in the program.

Abbey felt the barriers to the provision of science communication training within the biotechnology curriculum would include financial constraints, the inability to attract sufficient students to make such a unit viable, and the difficulties associated with the recruitment of a science communication specialist. Pierce also acknowledged that students may not see the value in science communication training: "They just don't seem to see the importance of it. They would rather do something which was expanding their knowledge of the scientific content rather than the communication aspects" (October 17, 2005).

The perception that a barrier to the introduction of science communication was an inability to attract sufficient students to make such a unit viable was also held by three other lecturers. Gareth stated "Most people just aren't that good at communication so you're teaching them something that most of them are not going to be good at, or don't even want to do" (October 20, 2005). John felt the perception of science communication training as a non-traditional science skill by lecturers and the science division as a whole, was a barrier to the provision of science communication training. And Owen stated:

It would be seen as a soft, wishy-washy type thing that you learn along the side and that most people really never need to. It's not seen as career forming. It is probably in a way seen as something that some people have and other people don't have. And they either can communicate and know

> what issues to treat carefully and what issues you can straightforwardly answer to in the case of the public interview or something [or they don't]. (Owen, December 14, 2005)

Finding 37: A number of barriers to the inclusion of science communication training within the biotechnology curriculum were identified by the lecturers. Half of the lecturers suggested a lack of space within the program would inhibit the inclusion of new material into the program. Half also indicated it would be difficult to attract students to enrol in the science communication units as the students do not attribute any value to this form of training.

When asked if they were aware of any material to support the provision of science communication training for biotechnology students, none of the lecturers could identify any specific material available. Seven of the ten lecturers indicated they should be aware of the material available. Five indicated they felt there would be teaching support material for them if they looked for it, particularly if they undertook a web search.

Finding 38: None of the lecturers were able to identify any teaching material to support the provision of science communication training for biotechnology students.

The lecturers were also asked about the feasibility of introducing science communication training into the biotechnology curriculum and what they felt the outcomes of improved science communication training of biotechnology students would be. While all of the lecturers except one felt the introduction of science communication training was feasible, some felt it was more feasible than others. Owen stated:

> It's feasible to put anything in, anytime. So no problem if it was deemed to be important enough....Realistically will it be done? As a full unit? I don't think the students would like it. (Owen, December 14, 2005)

Concerns about student interest and the crowded curriculum were again raised by four other lecturers in response to this question, including Pierce who stated:

> Given the constraints that I've already indicated it does make it difficult [to introduce into the curriculum]. And it's probably significant that when we had this review meeting – we've got the last review meeting next week – we had a whole range of priorities that we anted to fit in there. Interestingly science communication wasn't one of them. And a lot of those priorities have actually had to drop out because we just couldn't find space for them. So I think it's going to be difficult. (Pierce, October 17, 2005)

There was clear acknowledgement by seven of the lecturers that implementation of science communication training for biotechnology students would take time, and Richard and David also felt it would need someone to "champion" the cause. As David stated "It's just a question of someone you know, taking that up or convincing those with the purse strings that this would be – that it's an important part of the education of scientists and scientific training" (February 16, 2006). Others felt it required support in the form of a ground roots movement. Richard (lecturer) stated:

> Maybe in time [it might be incorporated into the curriculum]. In some ways biotechnology is still a young science, a bit of a baby, and science communication is even younger.....what it actually needs, is another generation before it becomes incorporated. (Richard, October 13, 2005)

Finding 39: While the introduction of science communication training into the biotechnology curriculum was considered feasible by the lecturers, many reemphasised the constraints to introduction of this material. Two lecturers felt the introduction of this material would require someone to champion the cause, or a ground swell movement of support for the area. Many indicated it would only be a matter of time before this material would be introduced into the curriculum.

6.5.3 Benefits of Improving the Science Communication Skills of Biotechnology Students

All of the lecturers who commented on the benefits of improving the science communication skills of biotechnology students described these benefits in terms of what the students would gain from improved science communication training, such as, an improved understanding of biotechnology, improved communication skills, improved employment prospects, improved acceptance of biotechnology and greater funding opportunities. Abbey said "I think it may employ, improve the employability of the students" (October 20, 2005). John stated:

> It's strange but twenty years ago scientists didn't need to talk about their work because you just got funded and you just went on and you did the next esoteric thing. Nowadays there's probably, you find me a grant where it says we'll give you some money just to do it for fun. It doesn't happen anymore. What will happen with your research, what are the outcomes, what will happen in the national interest, the state interest or whatever?......I couldn't name you a grant where they said just do it and we'll give you some money. (John, November 4, 2005)

None of the lecturers, with the exception of David, discussed outcomes in terms of the broader community. David felt that improved science communication training for students would lead to a greater appreciation of the importance of communicating and ultimately, better interactions between scientists and science communicators.

Finding 40: All of the lecturers described the benefits of improving the science communication skills of biotechnology students in terms of what the students would gain from improved science communication training. These benefits included improved understanding of biotechnology, improved communication skills, improved employment prospects, improved acceptance of biotechnology by the public, and greater funding opportunities.

6.5.4 Nature of Science Communication Training

The lecturers were also asked in their interviews if the skills required for science communication with non-scientists are significantly different from those required for communicating with fellow scientists. Only one lecturer, Abbey, felt there was no difference between the two. Abbey felt science communication required scientists to speak with "truth" and "clarity", irrespective of whether they were communicating with the public or with fellow scientists (October 20, 2005). Two other lecturers spoke of the similarities between the two forms of communication: the requirement for information presented in context, clarity, the correct level of information, and an awareness of the audiences' understanding and knowledge of the science to be discussed. Alan (lecturer) stated:

> The same principles apply, you know. Know what you're talking about, be clear about what message you're trying to what information you're trying to convey, and understand your audience. And provide it in a format and language that is appropriate to the audience. So you've got to spend a lot of time on knowing whom you're trying to communicate with so that you can shape your presentation to that. (Alan, December 9, 2005)

The remainder, while indicating they felt there were significant differences between these two forms of communication, indicated that the differences lay in how information was presented. These remaining seven lecturers spoke of simplifying or filtering scientific information before it is communicated, communicating in layman terms and not presuming any background understanding. Richard (lecturer) indicated he felt communicating with non-scientists required researchers to "distil and simplify very complicated things into clearly understandable things" (October 13, 2005).

Finding 41: The majority of the lecturers indicated scientist-to-scientist communication varied significantly from the skills required for public engagement.

6.5 Science Communicators' and Science Communication Lecturers' Views of Science Communication Training

In their interviews the science communicators and science communication lecturers were asked similar questions with respect to science communication training, and the responses of these two stakeholder groups have been combined in this section. They were asked if they felt science communication training should be a component of the undergraduate education of biotechnology students and were asked to identify supports and barriers to the provision of science communication training within the biotechnology program. They were also asked to identify the possible benefits arising from the improved science communication training of students within the program.

The science communicators and science communication lecturers were also asked a series of questions aimed at examining whether they felt the current state of the biotechnology curriculum provided the students with adequate skills for public engagement. In addition, they were asked questions about whether scientist-to-scientist communication differs from the form of communication that occurs between scientists and the public, and whether the generic skills training offered to biotechnology students equips these students with sufficient skills for public engagement once they enter into the workforce.

6.5.1 Inclusion of Science Communication within the Biotechnology Program

The science communicators and science communication lecturers were asked in the interviews if they felt science communication training should be a component of the tertiary education of biotechnology students. This group unanimously agreed that science communication should be included in the training of undergraduates. When asked to elaborate on how they would see this training delivered, two of the science communication lecturers (Tess and Cate) acknowledged the value of having science

communication training offered as an elective unit. Cate felt an elective unit promoted cross-disciplinary enrolments in the unit that enabled the students to reflect on how they communicate to people outside of their immediate speciality:

> Well, our model is electives because – and one of the strengths of that and one of the reasons, I think, it's – that I would push that, continue to push that at [my university] is that – and you know, hold it up as a model for other universities – is that when scientists, science students in a unit have to explain something to other science students and they realise, they recognise that their colleagues in the class are intelligent people and if they can't understand what I'm talking about, well then what hope does the public have? And so it's a very good first step at getting them to strip away their jargon because they – in a way, they will acknowledge that their audience is intelligent, you know, so it's not – it gets away from this myth that science communication is about dumbing down science. That really irritates the hell out of me. (Cate, October 27, 2005)

Charles, in contrast, felt science communication training needed to be made compulsory for science students because the need for scientists to be trained in this area is so great. He stated "Communication should be seen as important so it ought to be compulsory. I always worry about making any unit compulsory but in this instance I think the need is so desperate that I would make science communication a compulsory unit" (Charles, November 11, 2005). Eight of the science communicators and science communication lecturers agreed that provision of science communication training should be compulsory.

Two of the science communicators stressed the importance of shifting the current training practice of scientists towards the fuller development of civic scientists. Erin spoke of the need for a "fundamental change in the paradigm which exists in tertiary education away from building researchers into building scientists" (November 28, 2005). Wendy expressed a similar sentiment when she stated:

> Basically the way I see it university is about, when you're doing science at university it's teaching you to be a scientist. So if you're not taught to communicate at university, you're going to be a scientist who's not going to communicate. So you need to be taught that at university. And if you're instilling that attitude at university, you're going to grow up to, you're going to develop into a scientist who's going to communicate. And I think, I mean, saying that it's got to be part of their job is sort of a, can be a bit of a rash statement. But I think in the interim it's only fair to expect that. But until we can, I think a better long term strategy would be to teach scientists to be communicators when we're teaching students to be scientists. It goes hand in hand. (Wendy, December 5, 2005)

Finding 42: All science communicators and science communication lecturers agreed science communication should be a component of undergraduate tertiary training. The majority indicated that this training should be compulsory, but two of the science communication lecturers felt this training should be offered as an elective unit. Two of the science communicators stressed the need for the inclusion of civic science in this training.

6.5.2 Supports and Barriers to the Provision of Science Communication Training

The science communicators and science communication lecturers were also asked if they were aware of any material that could be used to support the provision of science communication training at the tertiary level. Not unexpectedly, the five science communicators who had indicated previously that they did not have any experience in teaching science communication at this level were not aware of any teaching material available in this area.

The four science communicators who reported having experience in teaching science communication (the three science communication lecturers and Erin who incorporates science communication teaching into her nanotechnology units), felt

there was a significant amount of science communication material available in the field of science communication but very little that specifically supported science communication teaching. All three science communication lecturers had spent considerable time and effort in preparing their own reading material for the students and did not rely on any one particular textbook or resource. Charles felt the textbooks available are "not particularly good" and lack an Australian context which make them difficult for Australian science lecturers to adapt for use in their classrooms (November 11, 2005). Tess and Erin expanded on this theme by stating:

> I don't think there is good material out there. There's good material if you want very superficial communication – there's some material, not a lot but if you really want communication that starts looking at the other person's perspective. It's not that accessible. .... I don't think there's a sort of nice standard text because it's a complex issue. It's not a complex issue if all you want to do is put some spin on and send it out. But if you want good communication then you've got to see the other person's point of view and that's mental effort. (Tess, October 31, 2005)

> I see two big faults with the materials available for people wanting to improve their own science communication and also teach it to the others – that there's the perception that peer communication is science communication and also the – largely it is, you know, built on the sponge model. How to identify the key messages, you know, stick to it in the first ten seconds, your grab kind of, that kind of narrow vein rather than dialogue type communication or it is written for schools. And, I guess, part of the problem is because it's come out of interactive science and technology centres, that it's informal science education, has really become the dominant form of science communication. (Erin, November 28, 2005)

Finding 43: While it was acknowledged that there is a large amount of material in the field of science communication, none of the science communicators and science

communication lecturers were able to identify any teaching material suitable for support the provision of science communication training for biotechnology students.

6.5.3 Benefits of Improving the Science Communication Skills of Biotechnology Students

When asked about the outcomes of improved science communication training for biotechnologists, the majority of the science communicators and science communication lecturers expressed these outcomes in terms of what society could gain from this training. This is in direct contrast to the lecturers who saw the outcomes of improved science communication training predominantly in terms of how scientists could benefit. The science communicators and science communication lecturers indicated that the biotechnology students would benefit from science communication training by gaining a greater appreciation of the value of science communication, improving their communication skills, improving their understanding of, and sensitivity towards, community views and concerns, and ultimately being better able to contribute to the community.

All three of the science communication lecturers felt improved science communication training would enable biotechnologists to better reflect on the aims and outcomes of their research. Charles felt science communication training could help students "reflect on the issues" and "confront them head on" (November 11, 2005). Tess felt that if scientists were not given the training and opportunity to communicate then they were not "working with society" and if they only communicated technical details then they "were not acknowledging the responsibility of their work" (October 31, 2005). Cate stated:

> I think, you know, scientists in general need to think about why. You know, so what? And why? Why is this important? Why are you doing what you're doing? And so what? Who cares? At a very early stage in their career because it will help them. (Cate, October 27, 2005)

When asked to comment on how feasible they felt the inclusion of science communication training within the science curriculum of all science students would be, the responses of this group were very similar to the lecturers. One science communicator felt it would require ground roots support, another three felt it would happen but not in the immediate future, suggesting that we are only making little progress towards the improved science communication training of biotechnologists and transforming biotechnology education is a slow process. Charles (science communication lecturer), who has lobbied for many years for his science communication unit to be promoted to biotechnology students, was more pessimistic. He stated: "I must admit I'm pretty negative. I don't think its going to happen…It's not a thing that the biotechnologists, or the industry, or the government seem to be interested in" (November 11, 2005). Erin (science communicator) felt the cause would need champions:

> It gets back, in a way, to that sphere of influence – start with those that you can affect change in and hope that you do a good enough job that it goes from being something that they do to something that happens automatically (Erin, November 28, 2005)

Finding 44: All of the science communicators and science communication lecturers described the benefits of improving the science communication skills of biotechnology students in terms of what the students would gain from improved science communication training. These benefits included improved understanding of biotechnology, improved communication skills, improved employment prospects, improved acceptance of biotechnology by the public, and greater funding opportunities.

6.5.4 Nature of Science Communication Training

The science communicators and science communication lecturers were all asked in their interviews if science communication training could improve scientist's capacity for civic science. Most (n=8) indicated they felt the provision of training could improve all scientists skills in this area, and three also felt practice in addition to training, was required. Erin (science communicator) stated:

> I think for some people it is, it is absolutely a talent or a gift. But it's not an excuse for why we don't do it and there's, you know, there's this tacit assumption – almost akin to, you know, student thinks 'Well, if I just sleep on the textbook or I read it once I'll actually learn the material'. There's almost from, I guess, my side - the teaching side – that, you know, if we, if we tell them why it's important then they'll just learn how to do it or they'll learn how to do it well. Those skills need to be cultivated. Now, I'm not saying at all that a fantastic researcher who has almost no personal skills should do those science communication outreach type things. They should definitely, within say a research organisation or a research team – identify people who are better at different things than other people. But I think everybody should have the ability to speak with authority and conviction about what they do. (Erin, November 28, 2005)

Wendy (science communicator), like lecturer John, indicated she felt science communication is a learnt skill, which is developed in some at an early age and often independent of tertiary institutions:

> I don't think it's an innate ability. I think in people that come across as being just natural communicators it comes down to their upbringing, their schooling. I mean, you've got those who will be public speakers from straight out of high school but again they may not – it again comes down to what they did. Look at the activities they were involved in and a lot of what you're involved in outside school, outside uni comes in handy. (Wendy, December 5, 2005)

There was also recognition by two of the science communicators that whether or not the skills training provided to biotechnology students improves their science communication ability may depend on who is delivering the skills training, and the context in which the training is delivered. Chloe (science communicator) felt given the right unit outline, the right teacher with the right skills and level of enthusiasm, some basic generic skills training may be all that biotechnologists require to improve their communication skills.

Finding 45: The majority of the science communicators and science communication lecturers indicated that all scientists could be taught how to communicate through the provision of training in this area and practice at applying these skills. Two of the science communicators felt the ability for this training to improve the students' science communication ability may depend on who is delivering the skills training and the context in which the training is delivered.

The science communicators and science communication lecturers were also asked if the skills required for science communication with non-scientists are significantly different from those required for communicating with fellow scientists. Two science communicators spoke of the similarities between the two forms of communication: the requirement for information to be presented in context, clarity, the correct level of information, and an awareness of the audiences' understanding and knowledge of the science to be discussed. Eight of the interviewees in this group (n=8), however, agreed there were significant differences between the two. They indicated they felt the information to be communicated needs to be presented in a different format, needs to be jargon-free, and is likely to be more interesting if it refers to the impact of research rather than the technical details of research methodology, funding issues and/or data analysis. Sarah (science communicator), who has extensive media experience, spoke of the need to simplify information for the media:

> I think to communicate with the non-technical public you do have to have better communication skills than when you're dealing with scientists, because you not only have to be able to regurgitate what your research is about, but

quite often you have to explain in very, very simple terms. You have to be able to explain that in terms of ultimate benefits and how it fits into big picture stuff. And with the non-scientific public, they really are interested in end points - Why are you doing this? What's it going to do for me? Which is stuff that scientists don't naturally sort of think about when they're doing their research. They think about it in sort of one piece of the jigsaw, and when talking to the other scientists are happy to keep on talking about that one piece of the jigsaw stuff. (Sarah, November 4, 2005)

Cate and Charles (science communication lecturers), both likened the ability of scientists to communicate with non-scientists to the ability to communicate in two different languages:

> We forget that we need to be bilingual. We need to speak in plain English because when we learn our own subject area and discipline we learn all the jargon that goes with it and when we talk about our discipline we continue to use the jargon, even when we're talking to people outside of the discipline. And that's what people need to re-learn – how to speak in plain English about their own discipline. (Cate, October 27, 2005)

> When you're communicating with other people you're communicating with people who share many of the concepts, and skills that you have. So if you say something, even if it's an acronym, immediately they will know. If you say ATP [adenosine tri-phosphate] they recognise and understand that. If you say ATP to a community group they won't have the slightest idea what you just said.....So I think that's the problem. In a sense it's almost like you're going to a new country. If you go to a new country you make all the efforts you can to properly understand the language, the currency, the customs. And that's in a sense what you do when you talk to community groups. You're actually in a different country. You're no longer in the country of scientists or biotechnologists, people who don't have the background. They haven't spent

seven years, ten years, twenty years working in this area. (Charles, November 11, 2005)

Three of the science communicators, Erin, Chloe and Jane, felt that science communication lacked an element of negotiation between scientists and non-scientists. Erin stated "scientists make a unilateral decision – this is what I'm going to tell them" (November 28, 2005). Chloe stated:

> I don't know many places that do it really well because they tend to come from a science is right perspective, rather than science needs to negotiate what's appropriate. So they ask the question 'Is it possible?' not 'Is it appropriate?' And so they come and tell you all the things they could possibly do with nuclear power, biotechnology, whatever it is – instead of negotiating with the general public. (Chloe, December 12, 2005)

Jane also stressed that the training scientists receive in how to communicate with their peers is not only different to the skills required to communicate with non-scientists, but can be a barrier to this process. Jane felt that while effective science communication between scientists and non-scientists should attribute equal value to the opinions of both parties, scientists are likely to enter into this process seeing themselves as representing a position of expertise:

> I think that peer-to-peer communications is not only different from non-peer communications. Actually, I think training in the scientific and engineering and technological communities - in terms that their training in dealing with each other, I think - is actually an obstacle. Because their status and the perceived value of what they say is associated with people's perception of their level of expertise. And it's not that that's not relevant when you're dealing with non peers. It's just that that's how people see the information that's in their head. Whereas I think they've really got to get to a position of real humility where they realise that what's in the layperson's head is just as important as what is in theirs. We cannot make a wise decision without both,

> that a position of educated or thoughtful ignorance, thoughtful ignorance is probably the only valid way to go forward. If we don't actually have a really good grasp of our own ignorance, then it makes it difficult. (Jane, November 15, 2005)

The science communicators and science communication lecturers were also asked if they felt generic communication skills training is sufficient for biotechnologists to develop an ability to communicate with non-scientists. Of the eight that answered this question, two felt this form of training was a "good start" (Sarah, science communicator, November 4, 2005) and "better than nothing" (Cate, science communication lecturer, October 27, 2005). Six of the eight indicated that generic skills training alone would be insufficient training because it would not provide the underlying rationale for why science communication is important and could not provide the science students with an understanding of science communication *per se*. For example, Jane and Charles stated:

> That sort of level is technically based. In other words it's about how can I improve my communication? That's important - what I call nuts and bolts - but the nuts and bolts has to be put into some sort of context. In other words we need to understand why are they doing this, what's the point, why we do want to communicate with people? And they need to understand it's not just a matter of communicating to, it's also listening. What are the community concerns? Are they real concerns? Are they perceived concerns? And whichever they are, they need to be tackled. (Charles, November 11, 2005)

> If we actually start thinking about what it means to play a civic role, to me that implies that it's not just about how do you get the public to understand what we're doing. A civic role, almost by definition, is how do we as a society make decisions? How do I play a responsible role in that decision making process?......How am I an active player, an active responsible player in that decision making process. And that's what it means for a scientist to play a civic role. (Jane, November 15, 2005)

Three spoke specifically of the need to learn communication skills in the context of science. Wendy (science communicator) said "I do believe that it has to be taught in a context because that gives people an understanding. It tests their understanding. I mean, communicating science isn't just about rattling something off" (December 5, 2005). Cate (science communication lecturer) noted a number of specific communication skills required by scientists:

> But I do think with science there is this specific role for unlearning jargon in science communication. The other thing is complexity of the issues involved and the fact that we're doing all these technological – making technological advances that are going to have huge impact on our whole society. And we, as scientists, just go 'Yep, this is great'. And we don't spend a lot of time – gross generalisation – thinking about the moral and ethical implications of our own research …There's a greater need for that in science communication. The other thing is how do you communicate uncertainty in the scientific process to the public, because I think that's a really important part of science communication……we say well, maybe and mmm, you know, all the time. It's so frustrating to the public. We need to learn how to minimise that while still staying true to our scientific understanding. Yeah, so there are a lot of specific things with science communication that I think could be much better explored in communication units that are specifically doing, you know, targeting scientists. (Cate, October 27, 2005)

There was also recognition by two science communicators that the generic skills training of early-career biotechnologists was often translated by lecturers into an oral presentation that did not necessarily teach students any skills.

> We can say that every student who graduates from this university will have given at least one, probably two, oral presentations in their career. That is not an oral communication skill because it doesn't demonstrate whether they've improved, whether they are good, whether they're bad, whether they've actually developed that skill. (Erin, November 28, 2005)

> I somehow feel some of those efforts are fairly superficial because often communication skills come across as being OK, you know, do an oral presentation for 20 minutes and that'll be worth 20% of your course, but students do not learn to communicate that way. They've practised communication but they haven't learnt to communicate. (Wendy, December 5, 2005)

Finding 46: The majority of the science communicators and science communication lecturers indicated that the skills required for science communication with non-scientists are significantly different from those required for communicating with fellow scientists, and generic communication skills training is insufficient training for biotechnologists to develop an ability to communicate with non-scientists. One science communicator felt the form of communication training that scientists receive could present a barrier to public engagement and two of the science communication lecturers felt scientists needed to be aware and proficient in both forms of communication. Three others noted the need for science communication training to incorporate fundamental aspects of science communication theory such as why public engagement is important for scientists.

6.6 Conclusions

The data from this chapter which addresses Research Question 3 indicates the majority of the early-career biotechnologists, lecturers, science communicators and science communication lecturers are supportive of the provision of science communication training for biotechnology students at the undergraduate or postgraduate level. The lecturers, however, were able identify a number of barriers to the provision of this training, notably the inability to find room for science communication in an already crowded biotechnology curriculum and a predicted lack of interest in science communication by biotechnology students. The responses of the undergraduate and doctoral students clearly supported this view, with the undergraduates rating science communication as one of the least important

components of a biotechnology program and the majority of doctoral students indicating they could not see the value in this form of communication training.

The majority of early-career biotechnologists, lecturers, science communicators and science communication lecturers also indicated that they felt the capacity for all scientists to engage the public could be improved with training. While many suggested the provision of generic communication skills training would be a positive inclusion within the training of science students, many felt public engagement requires specialist understanding, knowledge and skill sets that cannot be provided by a generic communication courses. Furthermore, while the undergraduate and postgraduate training programs provide the students with training in how to communicate with their peers, scientist-to-scientist communication was seen to be significantly different to the processes involved in public engagement.

Both the lecturers, science communicators, and science communication lecturers were able to describe numerous benefits of science communication. The biotechnology lecturers saw these benefits in terms of what the students would gain from improved science communication training. In contrast, the science communicators and science communication lecturers saw the benefits in terms of the gains the community would make from improved public engagement in science, including biotechnology students' greater appreciation of the value of science communication, and greater understanding of, and sensitivity towards, community views and concerns. All of the science communication lecturers indicated that improved science communication training would enable biotechnologists to better reflect their practice and be better civic scientists as a result.

Overall, however, the lecturers, science communicators and science communication lecturers were pessimistic about the likelihood of inclusion of science communication training within the science curriculum in the short term. In the long term, some were optimistic that biotechnology education would be slowly transformed in a manner that would favour the introduction science communication training within the tertiary training of science students.

7. DISCUSSION

The results presented in the previous three chapters of this case study describe the status of science communication training within an undergraduate and postgraduate biotechnology program, the stakeholders' views of science communication and science communication training, and the factors that may facilitate or inhibit the provision of this training. The present chapter begins with a brief summary of these chapters then returns to the conceptual framework underpinning this study and discusses the results with respect to the three spheres represented in the framework (tertiary education, biotechnology, and science communication). The implications of these results for the development of civic scientists through science communication training are then explored by drawing together the data from each of the framework's spheres.

In light of this exploration of civic science and science communication training, the conceptual framework is then reconsidered and revised. It is anticipated that consideration of the revised conceptual framework and how it may need to be transformed will provide an improved understanding of how science communication training for tertiary biotechnology students can be improved.

7.1 Summary of Results

The results presented in Chapter Four which explore the current status of science communication education for tertiary biotechnology students in the case, suggest that science communication training for the students within this program is poor. Very few of the students and graduates of the biotechnology program indicated that their degree program provided them with any form of science communication training. Very few of the lecturers were able to identify where in the biotechnology program the students are taught communication skills beyond the provision of report writing skills, and there was little encouragement for the students to enrol in the communication units and courses available. The apparent absence of any form of

formal science communication training for the biotechnology students in this case study suggests these students' are unlikely to enter the workplace as capable civic scientists.

While science communication training at the undergraduate and postgraduate level in the biotechnology program is poor, the results described in Chapter Five suggest that most of the participants in the case study feel that biotechnologists should be involved in some capacity in engaging the public in science. In Chapter Five, the impact of stakeholders' views of science communication on the provision of civic science training for students in the biotechnology program was explored. Despite many of the stakeholders agreeing that biotechnologists need to take on a civic science role, there was significant variation in the stakeholder groups with regard to their views of the relative importance, nature and scope of this activity.

While the undergraduate students' acknowledged that it is important that non-scientists understand biotechnology, they did not feel that communicating with the public is as important as communication with other groups. The early-career biotechnologists and lecturers indicated that science communication should not be compulsory for biotechnologists and were supportive of using science communicators as a buffer between scientists and the public. In contrast, the science communicators and science communication lecturers indicated they felt there was a role for all scientists in public engagement and were able to identify a number of drawbacks stemming from a lack of direct engagement between scientists and the public. The results from Chapter Five also indicated that many of the science communicators felt biotechnologists are not sufficiently aware of the approaches they should take to public engagement and could benefit from science communication training that focuses on the understanding of what science communication is and why it is important.

The stakeholders' views of science communication training for undergraduate and postgraduate students in the biotechnology program were explored in greater depth in Chapter Six. The results presented in this chapter suggest that while the many of

the stakeholders in the case are supportive of the provision of science communication training for biotechnology students at the tertiary level, there are a number of barriers to the provision of this training including a crowded curriculum and a predicted lack of interest in science communication by biotechnology students. The responses of the biotechnology students towards science communication training clearly support the perception that these students do not value this form of training.

Chapter Six also showed that the majority of stakeholders in the case study feel the capacity for scientists to effectively engage the public could be improved with science communication training. Many indicated that public engagement requires specialist understanding, knowledge and skill sets that cannot be provided by a generic communication skills training. And while the undergraduate and postgraduate training programs provide students with training in how to communicate with their peers, scientist-to-scientist communication is significantly different to the processes involved in public engagement.

The benefits of improved science communication training for biotechnology students were also explored in Chapter Six. While the biotechnology lecturers expressed these benefits in terms of what the students would gain from improved science communication training, the science communicators were more likely to see these benefits in terms of the gains the community would make from improved public engagement in science. However, while the many of the stakeholders could outline the proposed benefits of science communication training at the tertiary level, many were also pessimistic about the likelihood of inclusion of science communication training within the science curriculum in the short term. The following section discusses these results in relation to the conceptual framework underpinning the present study.

7.2 Conceptual Framework

The focus of the present study is the intersection between the three spheres of the conceptual framework: biotechnology, tertiary education, and science communication. In the discussion of the case study that follows, the views of stakeholders from all three spheres represented in the framework are considered.

From the tertiary education sphere of the conceptual framework, the views of undergraduate biotechnology students, the postgraduate students enrolled in the biotechnology doctoral program, and the lecturers and supervisors of these students in the case study are explored. Exploration of the views of these stakeholders provide a rich description of science communication training within the biotechnology program in this case study from the perspective of both student and teacher. A number of these lecturers and supervisors also present their views from a position that is also informed by experience in biotechnology research.

From the biotechnology sphere of the conceptual framework, the views of early-career biotechnologists are explored. Exploration of the views of this stakeholder group provides a rich description of science communication training from the perspective of a biotechnologist new to the workplace. As these early-career biotechnologists are also graduates of the biotechnology program, their perspective contributes to an understanding of how this program in particular prepares its graduates for civic science in the workplace.

Finally, from the science communication sphere, the views of science communicators and science communication lecturers are examined. Exploration of the views of these two groups of stakeholders provide a rich description of science communication training within the biotechnology program in this case study from a perspective external to the case study, yet informed about science communication and the practice of science communication training. As some of science communicators were biotechnologists or scientists in another discipline prior to commencing their careers as professional science communicators, these science

communicators also contribute views informed by their experience as scientists and science communicators. In the case of two of the science communication lecturers with a background in science, their perspectives are also informed by their prior scientific practice.

7.2.1 Perspectives from the Tertiary Education Sphere

The results from the stakeholders in the tertiary sphere suggest there is a lack of formal science communication training for the undergraduate biotechnology students in the case. This is likely to be a major factor contributing to their limited understanding of science communication. Science communication is the effective communication of information about science and technology, and in the broadest sense this encompasses both the forms of communication that occur between scientists and the forms of communication that occur between scientists and non-scientists. It has been suggested that these forms of science communication are distinct and scientists need to be able to skilled at both of these very different modes of communication (Aikenhead, 2001; Holten, 1978). In the present study, very few students acknowledged that science communication could involve both scientist-to-scientist communication *and* public engagement. Given that the only form of assessable science communication training the students are provided with in their degree program is formal report writing, it appears unlikely that the students are aware of the differences between these forms of communication and even less likely that they are skilled in both.

None of the undergraduate biotechnology students in the case study acknowledged that science communication could involve the mutual transfer of information between scientists and the public through open and equal dialogue, with some defining science communication as a one way transfer of knowledge from scientists to non-scientists. Known as the deficit approach to science communication (Clark & Illman, 2001), this approach assumes that non-scientists respond negatively to science and technology primarily because of a deficit in scientific knowledge, and

understanding and acceptance of science can be achieved by the provision of sufficient scientific information to reduce this deficit.

Since the *Public Understanding of Science* report first sanctioned the deficit model two decades ago (Bodmer, 1985), science communicators' and policy-makers' approaches to science communication have advanced significantly. It is now felt that support for science cannot be achieved through improving the understanding of science alone. Science communication must attempt to build trust through dialogue in which participants must be aware of, respectful of, and responsive to the knowledge and concerns of all groups involved (Clark & Illman, 2001). Despite widespread support for scientists to revise their approach to science communication to encompass this revised form of public engagement, evidence suggests many scientists still see education of the public as the primary reason for science communication (Royal Society, 2006b). The results of the present case study suggest the next generation of biotechnology graduates may also hold these outdated views.

In the present case study, science communication training is available to the undergraduate students in the form of an elective unit, offered externally to the science division. This unit aims to provide students with an understanding of science communication, the dominant models of science communication, and the contexts in which science communication occurs. The undergraduate students' lack of understanding of science communication (and in particular their outdated views of the purpose of public engagement) may be addressed by ensuring they complete this unit. However, none of the biotechnology students participating in the case study, either undergraduate or postgraduate, had enrolled in the unit and many were unaware the unit existed.

Two of the factors contributing to the lack of biotechnology students enrolling in this unit may be that the unit is not offered by the science division of the university and it is not widely promoted as a recommended elective to the students. While improved promotion of the science communication unit to the students and lecturers in the science may increase their awareness of the unit, the results of the case study suggest

promotion of this unit alone is unlikely to improve biotechnology student enrolments in the unit. When informed that a unit in science communication was available, none of the students in the case study indicated they intended to enrol.

One lecturer suggested that biotechnology students who see themselves as developing research careers may not see sufficient value in science communication to choose this unit over other available electives. Another of the biotechnology lecturers suggested the relevance of this unit to science students may always be questioned because it is not offered from within the science division. The funding structure of the university, in which programs are partly funded on the basis of the number of students enrolled within units in the division, may also reinforce promotion of elective units offered from within the division in preference to others. For these reasons, it seems unlikely that a majority of biotechnology students will elect to enrol in this unit if it continues to be offered externally to the science division. Alternate forms of science communication training offered from within the science division are likely to be required for these students to gain a better understanding of science communication and develop the skills required for scientist-to-scientist communication and public engagement.

While the biotechnology students' showed a lack of understanding of science communication that may be attributed to a lack of science communication training, both the undergraduate and postgraduate students did agree that biotechnologists have a role to play in science communication and acknowledged that it is important for non-scientists to understand biotechnology. However, from further analysis of the undergraduate students' responses it appears that many of these students equate an improved public understanding of science with improved acceptance of science. Furthermore they do rate public engagement highly in comparison to communicating with other possible audiences, such as fellow scientists, government and industry. This suggests that while these undergraduate biotechnology students are supportive of biotechnologists' role in science communication, they have little understanding of its function and feel public engagement is a low priority in comparison to other forms of science communication.

In the *Role of Scientists in Public Debate* survey (Royal Society, 2006b), scientists were asked a similar question to these undergraduate biotechnology students. When asked "How important do you feel it is that you personally, in your current post, directly engage with each of the following groups about your research?" 60% of the scientists afforded policy makers (60%) and 47 % afforded industry a high level of importance. In contrast much lower levels of importance were afforded to media representatives, non-government organisations, and the non-specialist public by many of the scientists.

The results of the present study in combination with the results of the *Role of Scientists in Public Debate* survey (Royal Society, 2006b) suggest that scientists, from very early in their career, see engaging with the public as something biotechnologists should be involved in principle, but in practice afford this activity little value. The low numbers of scientists participating in public engagement is likely, in part, to reflect the low level of importance attributed to these activities. For scientists to engage with the public in a systematic way, it is likely that scientists will need to move beyond appreciating the need to participate in public engagement, to acknowledging the importance of their own participation in these activities and rating public engagement of equal importance as all other aspects of scientific practice. The results of the present study suggest this required attitudinal change may need to be explored as early as the undergraduate years.

The results of the Wellcome Trust poll of UK scientists (Wellcome Trust/MORI, 2000) and the present case study, indicate that communicating with the media is ranked low in importance by both the scientists and students surveyed in these studies. A culture of distrust of journalists and broadcast media (Triese & Weigold, 2002) has been identified as a significant barrier to involvement of scientists in science communication programs and activities, and results from this case study suggest this distrust may begin as early as the first few years of science training. As the media is an important conduit through which science and technology is communicated and the bulk of science communication programs focus on communication through television and print media (Borchelt, 2001), effective

interaction of scientists with the media is required for public engagement. Media training for scientists aimed at increasing their ability to interact effectively and comfortably with media representatives is therefore clearly warranted. However, as the present study has indicated that undergraduate students have a strong mistrust of journalists, this training will initially need to redress students' negative views of working with the media.

While media training is clearly desirable for scientists, there is increasing recognition that other forms of public engagement, including interactions at work, at home and in education settings, also have an important role to play in science communication (Borchelt, 2001). Media training in isolation, therefore, is unlikely to be sufficient training for scientists' wishing to engage in other ways with the public. Science communication training will need to address not only the basic skills required to work with the mass media, but will also need to provide training in all other approaches to public engagement. In the present case study, the lecturers report concentrating their science communication training almost exclusively on developing undergraduate students' report writing skills.

In addition to the elective unit in science communication offered to the undergraduate students, the doctoral students enrolled in the biotechnology program are able to enrol in a communication course that aims to equip them with generic communication skills. The university stipulates in its *Research Student Supervisor Policy* that supervisors should arrange any training necessary for their students including the generic skills communication training course. Despite this, none of the doctoral students reported being encouraged to enrol in the generic communication skills course or participate in public engagement activities by their supervisor, suggesting the supervisors did not see this training as necessary for their students' research degree. None of the postgraduate students had completed the course. As research supervisors are in the best position to provide guidance to their students, their mentoring with respect to science communication training may need to be explored if the civic science capacity of these doctoral students is to be improved.

The mentoring process in postgraduate studies is an integral part of postgraduate training. In the NIH report *Adviser, Teacher, Role Model, Friend: On Being a Mentor to Students in Science and Engineering* (NIH, 2002), a mentor is defined as a "person who has achieved career success and counsels and guides another for the purpose of helping him or her achieve like success". The report suggests that research supervisors have a responsibility to discuss with and advise their students on aspects of their work and professional development, including science communication. Others have also noted that enthusiasm for communicating science with diverse audiences can be "very valuable training" for students and "great mentors" encourage their students to develop these skills (Lee, Dennis, & Campbell, 2007, p. 797). Greenwood and Riordan (2001, p. 34) state that "Established scientists, especially those who are nationally and internationally known, have a special opportunity, even an obligation, to stimulate and encourage the best scholarship of faculty and students as well as good citizenship and public service'. The Royal Society (2005) also acknowledges the need for establishing role models and advocates for public engagement.

A recognised difficulty in mentoring at the postgraduate level is getting the right balance in guidance. According to Lee and coworkers (Lee, Dennis, & Campbell, 2007) encouraging independence and nurturing creativity is paramount, but students should not be given so much freedom that the only way they learn is through their mistakes. In the present study, independence was a term that came up repeatedly in the doctoral student interviews. Whilst developing independence is clearly an important aspect of research training at this level, these students are still require mentoring in science communication. The level of support and encouragement for science communication provided by supervisors is likely to have an influence on enrolment in generic communication skills course and participation in scientist-to-scientist and public engagement communication activities. And if these students are to improve their civic science capacity they will not only need support for their science communication activities, but supervisors will need to provide sufficient guidance and feedback to enable the students to learn from their experiences. This is

likely to require increased understanding and appreciation of the value of public engagement by both the students and the supervisors.

When asked why they had not undertaken any science communication activities, a number of interviewees cited commercial issues as a significant barrier to engaging the public in their research. As noted by the International Council for Science (ICSU), a non-governmental organization that provides a forum for discussion of issues relevant to policy for international science, science has changed in the 21st Century and finance and commercialisation are having a major influence on the practice of science (ICSU, 2005). Ziman (2000) suggests we are radically and irreversibly moving towards "industrialized" science where researchers are funded by private corporations and research is commissioned and proprietary. Public interest in research, however, is not limited to publicly funded research but also is in research from private or commercial sources. The Royal Society (2006a, p. 10) suggests that "considerations of intellectual property rights, commercial confidentiality and security, whilst important, should not invariably prevent the research community within the private sector from meeting their responsibilities with respect to the communication of research results that have implications for the public". This is another aspect of science communication that will invariably require mentoring by supervisors to ensure that students are encouraged and able to engage in science communication activities despite the perception of possible commercial barriers.

The perception that communication with non-scientists should only occur in response to a request for information from an interested party, was also cited as a barrier to public engagement by the doctoral students. Using the UK's Freedom of Information Act (*Freedom of Information Act, 2000*) as a guide, the Royal Society makes it clear that information *in the public interest* should be distinguished from information that is *interesting to the public* (Royal Society, 2006a). In general, the public interest is served where access to a piece of information can: further the public's understanding of, and participation in, the debate of issues of the day; facilitate accountability and transparency of researchers, funding bodies, and employers; allow individuals to

understand how the results of research affect their lives and, in some cases, assist individuals in making informed decisions in light of the results; and bring to light information affecting public well-being and safety. Clearly this is another area where student mentoring is likely to be of paramount importance as research supervisors would be better placed to determine if the students' research is in the public interest.

In many cases the students' research may be considered too premature to be of public interest. While this may preclude them from engaging with the public about specific aspects of their research, it should not preclude them from participating in science communication activities altogether. Research students are likely to need the opportunity to practice their science communication skills and it is likely that they could engage with the public with regard to a number of broad areas linked to their research. Research supervisors may need to be aware that there are many ways in which scientists can engage with the public, and many areas of science which can be communicated. Research supervisors may also need to encourage this engagement whilst monitoring the students' research for possible areas of public interest and communication.

While the inclusion of science communication training in the postgraduate program as recommended by the *Science and Society* report (House of Lords, 2000) may be effective for improving the science communication capacity of postgraduate students, a proportion of undergraduate students will not undertake studies at this level. If science communication is to be included "in every scientist's job description" as recommended by Borchelt (2001), science communication training may need to be included in the undergraduate program to ensure all students graduate with the required level of science communication understanding and skills to take on this role. The inclusion of science communication training in the undergraduate program is likely to improve graduates' understanding of the importance of civic science and ability to take on this role voluntarily.

While changes to science communication training of both the undergraduate and doctoral students in this case study is clearly required, these changes will need to

take into account the value these students place on science communication training. The results from both the undergraduate and postgraduate students suggest they view this training as one of the least important components of their degree programs. From the follow-up interviews it was evident that some undergraduate students ranked the communication with non-scientists item as a relatively unimportant component of their training because they did not value public engagement. Others felt science communication training is only required for students who intend to become specialist science communicators, not those who intend to pursue careers as research scientists. These views of science communication and science communication training may also be shared with undergraduates enrolled in other science programs, as the results obtained for the biotechnology students in this case study were comparable to the results obtained for the other science students surveyed. Overall, these results suggest that if science communication training is offered at the tertiary level as an elective unit, it will need to be seen as valuable by the students if they are to enrol. Currently, these students do not appear to value this form of training.

Given that many of the undergraduate and doctoral students do not have a good understanding of science communication, and many do not value science communication training, the provision of an elective science communication unit may only attract those students with a pre-existing interest in science communication. A number of the students and lecturers suggested that science communication training would be better offered as a postgraduate course for students interested in pursuing science communication careers. Errington and coworkers (Errington, Bryant, & Gore, 2001), however, suggest that offering postgraduate programs in science communication is like "preaching to the converted" as the graduates in the program already have a keen interest in science communication, generally have quite good communication skills, and generally find employment within the science communication industry. If science communication training does not reach science graduates who remain in mainstream science research, their civic science skills may never be fully developed and public engagement may not be improved.

Despite very few of the biotechnology lecturers incorporating science communication training in any formal way into their teaching practice with the exception of report writing, many indicated they would like science communication training included in the biotechnology program. Ideally, they would embed this form of training within existing units. As evidence from the USA's National Research Council (NRC) suggests in-depth knowledge of a subject is best understood when learnt within a rich context (NRC, 2000) delivering the material within existing units may be the preferred option. However, it would require the lecturers of each of the units to teach the fundamentals of science communication theory and practice in the context of their unit. Given many of the lecturers indicate they do not currently teach science communication and very few have significant experience in this area, it is likely that this would require many of the teaching staff to undertake professional development in this area in order to teach science communication confidently and effectively. As command of the subject and enthusiasm have been identified as two components of effective teaching performance at the tertiary level (Hildebrand, 1973; Sherman, Armistead, Fowler, Barksdale, & Reif, 1987), professional development for these lecturers will need to aim to improve their understanding of science communication, teaching strategies, and an enthusiasm for teaching this material.

The assessment of any science communication material included within science units may also need to be carefully considered. Assessment regimes are thought to be one of the most important factors defining the curriculum and changing assessment regimes are a powerful means of changing students' learning practice (S. Brown & Knight, 1994; Ramsden, 1992). In the present study none of the biotechnology lecturers formally assessed any science communication skills within their units, other than oral presentation skills and report writing skills. Careful consideration of how science communication material may be assessed and how this assessment may influence student learning in this area is clearly required. The inclusion of assessable material may not only shape the students understandings of science communication, but may also help to reinforce that science communication is a valued part of science. If science communication remains an unassessed component of a degree

program, it is possible the students will view this science communication as an *optional extra* rather than an integral part of their training.

A barrier to the introduction of science communication within the science curriculum may be the perception of science communication as a *soft* science. Qualitative data obtained from the Royal Society's *Survey of Factors Affecting Science Communication* (Royal Society, 2006b) suggest that some researchers believe that public engagement is a "light" or "fluffy" activity undertaken by those who were "not good enough" for an academic career. These views were shared by a number of interviewees in the present case study. Autonomy is a central feature of Australian universities and each institution has the freedom to specify its own modes of teaching and research and the range and content of educational programs. As such, university curricula reflect the values of the teaching staff and working to change established approaches and attitudes in tertiary education is a difficult task. Until the scientific community and science lecturers in particular, see science communication as an integral and valued component of science, it may be difficult to find support for the inclusion of this form of training within the tertiary science curriculum.

There is recognition by some individuals in the present case that the sole responsibility for science communication training may not lie with undergraduate lecturers or supervisors alone. Employers may also have a responsibility for the training of scientists in science communication with ongoing professional development in the workplace that complements and reinforces the fundamental science communication training provided at university.

7.2.2 Perspectives from the Biotechnology Sphere

The views of the early-career biotechnologists from the biotechnology sphere support the results derived from the tertiary biotechnology sphere. As graduates of the program, and therefore representatives of both the biotechnology sphere and the tertiary education sphere, these early-careers biotechnologists recollect receiving

very little training in science communication in their degree program. The similarity of the early-career biotechnologists and biotechnology students' views of science communication and science communication training also suggest that students' views of science communication do not change significantly when they enter the workforce. This is likely to result, in part, from a lack of science communication training at university or in the workplace. Only one of the six interviewees had been provided with any formal training in science communication since graduating. For most of these biotechnologists, science communication has not been a part of their training and is not a part of their professional development, and it is conceivable they may never receive any formal training in science communication in the course of their career. Evidence from other studies suggests up to three quarters of scientists do not receive any formal training in science communication (C. P. Brown, Propst, & Woolley, 2004; Wellcome Trust/MORI, 2000).

Despite this lack of training, the majority of the early-career biotechnologists interviewed in the present case study felt equipped to communicate about the technical details of research. They did not feel as well equipped, however, to discuss the social and ethical implications of their research. Similar results to this were observed in the Wellcome Trust survey of UK scientists, which found that three quarters of scientists surveyed felt equipped to communicate the scientific facts of their research, but only 62% felt well equipped to communicate the social and ethical implications of their research (Wellcome Trust/MORI, 2000). Whether feeling *equipped* or *well equipped* to communicate translates into effective practice in science communication has yet to be determined. Given the lack of training of biotechnologists reported in the present case study, these career biotechnologists are likely to have a limited understanding of this field. While they may feel equipped to communicate, how effective they are in practice in engaging the public in dialogue about their research is unknown. Training in science communication may influence the way these early-career biotechnologists approach public engagement by addressing their limited understanding of civic science, and by making them better equipped to engage not only in debate about the technical details of their research but also the social and ethical implications of biotechnology.

The failure of the biotechnology industry to develop programs to deal with the concerns of the public by addressing the social and ethical implications of research has been described as a "major blunder that will not be easily overcome" and genetic engineering has been described as providing "an object lesson in how not to communicate" (Bryant, 2003, p. 357). The early-career biotechnologists and many other participants interviewed in this case study agreed that overall, biotechnology has not been communicated well. There was also recognition across the stakeholder groups interviewed that the communication of biotechnology is complicated in part, by difficulties in defining biotechnology. France and Gilbert (2006) who aim to develop a model for communication about biotechnology, acknowledged the difficulties faced by the public in defining what biotechnology is. In particular, they suggest the public may have difficulty in distinguishing genetic engineering from genetic modification and may confuse biotechnologies that incorporate genetic modification from those that do not. As the publics' views of biotechnology are not uniform and vary according to the specific application of the technology (Hornig Priest, 2001), science communication training for biotechnologists may need to emphasise the importance of explicitly describing the nature of the biotechnology research being communicated, specifying whether or not the technology involves genetic engineering or modification, and clarifying how the technology may be applied.

In their interviews, a number of early-career biotechnologists indicated that the public misunderstands biotechnology and needs to be told the *truth*. This group also suggested that biotechnology communication could be improved by addressing any misconceptions that the public have about biotechnology - views that are consistent with the views expressed by the undergraduates in the present study, the scientists surveyed in the Wellcome Trust poll (Wellcome Trust/MORI, 2000), and the scientists surveyed in the *Factors Affecting Science Communication* study *(Royal Society, 2006b)*. These views suggest the early-career biotechnologists main motivation for engaging with the public is to *educate* them rather than enter into genuine dialogue. These scientists do not appear to recognise that the goal of public engagement is not compliance but informed critical engagement. In this engagement

process, scientific authority and expertise are not removed but become one form of expertise represented in dialogue positioned in the wider social context (Royal Society, 2006b). Another form of expertise in the wider context may be the publics' views of biotechnology. According to the Haste (2005, p. 10):

> Throughout all of this is the underlying need for scientists and policy makers to acknowledge public views and opinions as legitimate. Therefore, a starting point for dialogue is that many categories of people have an interest in, and indeed expertise relevant to, developments in science that affect them. Furthermore, allowing only one group of experts to define the terms of reference will constrain what is included in the deliberations – at cost to the value of the discussion, as well as the credibility of those discussions amongst the wider public who are affected by them.

While nearly all of the early-career biotechnologists interviewed agreed that biotechnologists have a role to play in public engagement, many supported the use of science communicators as an intermediary between scientists and the public. They were more likely than the stakeholders from the science communication and tertiary science spheres to feel that a compulsory science communication role for biotechnologists would be unreasonable. They indicated they felt those that choose to limit themselves to research should have the right to do so, and in many cases this may be preferred as forcing scientists with poor communication skills to engage with the public may be detrimental to the discipline as a whole. This group, as well as stakeholders from the other spheres, portrayed researchers as passionate, focused and disconnected individuals. This was often used to give legitimacy to the refusal by some researchers to participate in science communication activities.

There are conflicting views in the literature about the personal role scientists should take in science communication, and the way in which the civic science role is viewed. The Royal Society concluded in the *Factors Affecting Science Communication* report (Royal Society, 2006b, p. 14) that it is "undesirable to require

all scientists to engage with the public". Clarke (2001, p. 5) suggests it is "important to recognise that some scientists are uncomfortable dealing with a non-specialist audience". She suggests that the best ambassadors for the profession are those who can "communicate comfortably, without jargon, in an appropriate context". Others contend that every scientist has a civic science role to play (Borchelt, 2001). Pitrelli (2003) suggests there is a constant exchange of scientific information in many contexts, and all scientists take on science communication roles whether they are aware of it or not.

Evidence suggests that scientists are more likely than not, at some stage of their career to communicate their research at some level. The *Factors Affecting Science Communication* survey (Royal Society, 2006b) found that over a twelve month period, 74% of scientists surveyed had taken part in at least one science communication or public engagement activity. Over half of those who did not participate stated they would like to spend more time on public engagement. While science communication training, therefore, is likely to be valuable for those who are naturally good communicators, scientists who do not choose to be high profile ambassadors for science are still likely to engage with the public at some stage and could benefit from training in this area. With increased pressure on scientists to communicate, the proportion of scientists engaged in science communication and their level of involvement is likely to increase. It is important to note however, that scientists should not see this role as requiring a high media profile, such as the role fulfilled by scientists such as Jared Diamond, Stephen Gould or Carl Sagan. Greenwood and Riordan (2001, p. 30) suggest these scientists should not be characterised as civic scientists, per se as this "would be too intimidating to the rest of the science community who have estimable, but less extraordinary, communications talents".

7.2.3 Perspectives from the Science Communication Sphere

The results from the stakeholders in the science communication sphere, the science communicators and science communication lecturers, suggest the level of science communication training provided to biotechnologists is insufficient and early-career biotechnologists in particular, are not sufficiently aware of the approaches they should take to public engagement. The science communication lecturers indicated that biotechnology students need training that extends beyond report writing and oral presentation skills – training that provides more than the tools with which to "spin" messages about biotechnology. Rather, they require training that focuses primarily on understanding what engagement constitutes and why it is important for biotechnologists and the biotechnology industry to engage with the public.

The science communication lecturers who currently teach this subject, report a lack of suitable material to support science lecturers in delivery of this subject, and believe this presents a significant barrier to the inclusion of science communication training within the biotechnology program. Two of the science communication lecturers have a background in science, and are therefore intimately aware of how relevant the available science communication texts are to scientific practice. As noted by the AUTC in their review of Australian biotechnology programs (Gray & Franco, 2003), there is a clear need for the identification and dissemination of best practice for teaching communication skills to biotechnology students. The development and/or dissemination of appropriate material to support the provision of science communication training by science lecturers within the tertiary science curriculum is also clearly required if training in this area is to be improved.

Overall, the stakeholders from this sphere were much more aware than the other stakeholders from the spheres of biotechnology and tertiary education, of the need for scientists to move away from a deficit approach to science communication towards dialogue. They were also more likely than the others to suggest that scientists should engage with the public directly and as a result many supported a

compulsory role for scientists in public engagement including communication of the social and ethical implications of research.

In the UK, a Wellcome trust survey found that 69% of scientists felt that they should be responsible for the communication of the social and ethical implications of science (Wellcome Trust/MORI, 2000). There is recognition, however, that scientists may not be comfortable with communication that extends beyond the technical details of their work. Chaisson and Kim (1999) believe that to be comfortable in this area scientists need a better understanding of the social sciences. They state "the world beyond the microscope, telescope, or carefully delimited and controlled site in which the natural scientist is most comfortable requires the natural scientist to resonate to, to provide counsel for, and participate in policy decisions that in turn require an expansion of mind and training into areas traditionally relegated to social science."

Since C.P Snow (1993) first stated that solving the world's complex problems would require collaboration between the natural sciences and social sciences by "bridging the two cultures between the sciences and the humanities" there have been renewed calls for an interdisciplinary approach to teaching in science. Eisen and Lederman (2005) suggest the current university education system generates scientists with little understanding of anything but science and non-scientists with very little understanding of science. In their opinion, this system discourages a "scientifically literate, critically thinking public" (p. 26). They advocate a interdisciplinary approach to teaching science that brings together "diverse groups of students, scholars and community members to inspire re-thinking of issues across a broad spectrum of disciplines, and in doing so, to teach non-scientists the science in a rich context and to teach scientists the context of the science" (p. 27). There was recognition from one of the science communication lecturers that encouraging multidisciplinary enrolments in science communication training courses could strengthen both the research and communication skills of science students.

Pitrelli (2003) also advocates bridging the sciences and social sciences through the introduction of at least one philosophy unit into the science curriculum. He believes philosophical training will provide a counterbalance to scientists "over-specialisation, over-compartmentalisation and ivory-tower mentality" (p.1) and augment their communication skills by improving their ability to interact with diverse audiences.

7.2.4 Returning to the Research Framework

The findings from the present study suggest that despite increasing calls for improved public engagement by scientists, there are still significant barriers to the introduction of science communication into the tertiary biotechnology curriculum. While the conceptual framework underpinning the present case study shows a clear intersection between the three spheres of tertiary education, biotechnology, and science communication, the exploration of these spheres in the present case study show the stakeholders in tertiary education and biotechnology have very little understanding of the objectives of science communication and science communication training. There is very little science communication training provided to biotechnology students apart form the provision of some report writing and oral communication skills training for scientist-to-scientist engagement, and science communication training is seen as a specialist form of training for students who will pursue careers in science communication as opposed to those who will enter into mainstream research careers. The biotechnology students, lecturers and early-career biotechnologists see engagement with the public as an *optional extra* to the practice of science, a *soft* science that is best brokered by science communicators, and a tool for improving the understanding and acceptance of science rather than establishing dialogue between scientists and the public. Overall, these results suggest the conceptual framework needs to be redrawn with limited connectedness between the tertiary education and biotechnology spheres and the sphere of science communication if it is to represent the actual state of science communication training within the biotechnology program explored in the present case study.

The following revised conceptual framework is proposed (Figure 11). In this revised framework, the tertiary education and biotechnology spheres remain connected as do the tertiary education and science communication spheres, but the three spheres no longer intersect. In this framework, science communication studies are represented by the intersection between the tertiary education and science communication spheres. Biotechnology students who progress through these studies into the science communication sphere (as represented by the orange arrow) emerge as professional science communicators.

Tertiary training in biotechnology is represented in this revised framework by the intersection between the tertiary education and biotechnology spheres. Biotechnology students who progress through these studies into the biotechnology sphere (as represented by the blue arrow) emerge as biotechnologists. They enter the biotechnology workplace without minimal science communication training directed at developing their understanding of, and skills in public engagement. To reflect this, civic science is no longer included in the framework. These biotechnologists then interact with the greater sphere of society preferentially through intermediary science communicators in the science communication sphere (as represented by the green arrow). As many approach this communication from a deficit perspective the arrow points in only one direction.

As there is little direct interaction between biotechnologists in the biotechnology sphere and the public in the sphere of society, the biotechnology sphere in this model is positioned outside the sphere of society. Godin and Gingras (2000) in their *Multidimensional Model of Scientific Culture* acknowledge that many scientists view science as external to culture. Bauer and coworkers (Bauer, Allum, & Miller, 2007, p. 90) suggest that while science and society remain as separate spheres, the dual problems of "the public's understanding of science and of scientists' understanding of the public are here to stay".

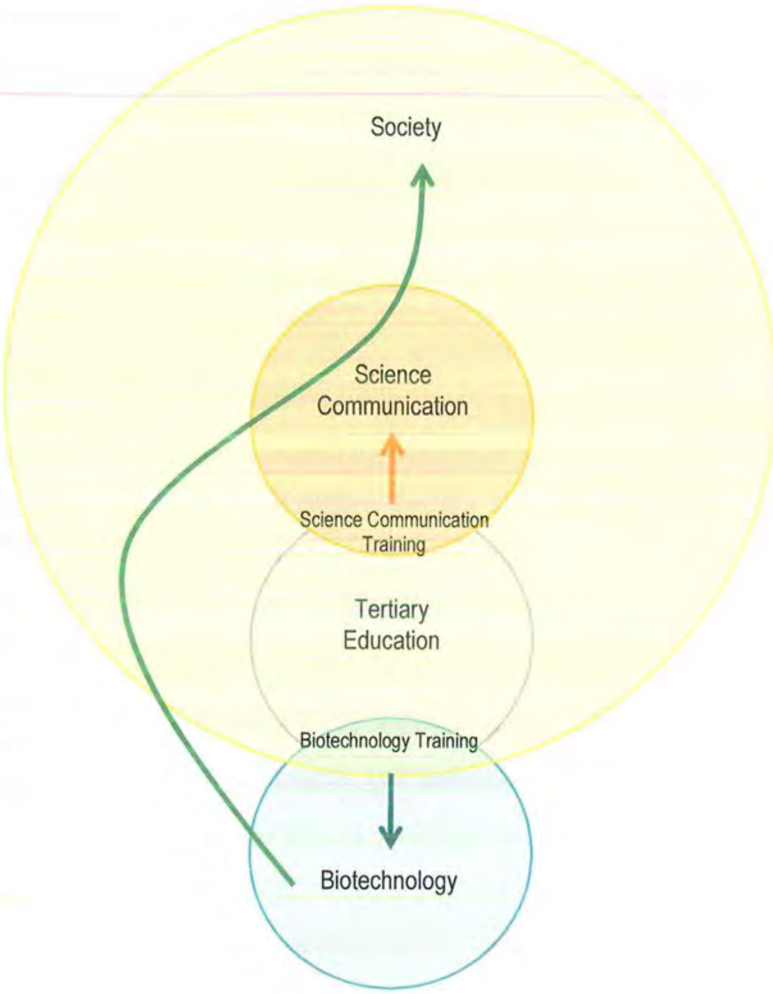

Figure 11: Revised conceptual framework drawn from the data obtained from the present case study. The tertiary education and biotechnology spheres remain connected as do the tertiary education and science communication spheres, but the three spheres no longer intersect. The biotechnology sphere is positioned outside the sphere of society.

Analysis of this revised framework suggests improving the provision of science communication training for biotechnology students in this case study may lie in returning to a conceptual framework that is closer to the original framework presented in this study. The spheres of tertiary education, biotechnology and science communication need to be drawn together, and science communication training needs to be seen as an integral part of tertiary biotechnology education. It is anticipated that by ensuring that biotechnology students are exposed to training that aims to improve their understanding and skills in public engagement, they will graduate as biotechnologists who value civic science, a proportion of which will go on to be effective civic scientists.

The revised framework also suggests that biotechnology needs to be better positioned within the sphere of culture. Biotechnology students, lecturers, research student supervisors and scientists need to appreciate that communication between science and society should be reciprocal and at this level, science represents only one sphere of expertise in the larger sphere of society. By interconnecting biotechnology with science communication and education, and thereby strengthening the science communication training of biotechnology students, these students will be in a stronger position to appreciate the place of science within society and act as civic scientists accordingly.

8. CONCLUSIONS and RECOMMENDATIONS

If biotechnology students are to enter into the workplace as scientists that are willing and able to engage with both their peers and the public in dialogue about their research, prior to graduating from their degree programs they will need to progress from merely acknowledging that science communication is required, to understanding what science communication involves, how it is best achieved, and why training in this area should be valued. It is unlikely this progression will occur unless these students are provided with formal training in civic science. Biotechnology curriculum planners will need to consider how students' views will impact on the choice of teaching material, how this material is delivered, and who it is delivered by. In particular, they will need to address the students' perception of the value of communicating with non-scientists and how receptive the students' will be to learning these skills.

This chapter discusses science communication training for tertiary biotechnology students based on the revised framework, and how biotechnology may benefit by moving away from this framework towards one that is closer to the conceptual framework originally presented in the introduction to this thesis. How future research in this area that may also contribute to a better understanding of, and improvement in, science communication training is also discussed. The chapter concludes with a series of recommendations aimed specifically at those involved in science communication training for biotechnologists, in particular curriculum planners associated with biotechnology programs with minimal science communication training. Combined with ongoing research in this area, it is hoped that these recommendations will lead to the improved science communication training and the civic science capacity of biotechnology students and ultimately, an improvement in the relationship between biotechnology and society.

8.1. Connecting the Spheres of Tertiary Education, Biotechnology and Science Communication – the Delivery of Science Communication Training

In the present case study, an elective unit dedicated to science communication is available to undergraduate students. If all students in this case study enrolled in this unit, the integration of biotechnology, science communication and tertiary education may be achieved. However, the current views of the biotechnology students and lecturers towards this unit and science communication training in general, suggest the enrolment of biotechnology students in this unit will always remain low. Furthermore, even if this unit was shifted to the science division, the low level of importance attributed to training in this area by the students suggests the science division would be equally unsuccessful in attracting biotechnology students to enrol. The provision of compulsory training in science communication may be the only way of ensuring that all the students in the program are provided with such training. Given the views of students and lecturers to the delivery of science communication externally to the science division, this training would ideally be delivered from within the science division.

Offering a compulsory stand-alone unit is one way of introducing compulsory material into the science curriculum. Given the results of the present study which suggest the lecturers are unwilling to deliver science communication training themselves, this would appear to be a logical option as a science communication lecturer could be contracted to fulfil this role. However, as in-depth knowledge is best understood when learnt within a rich context (NRC, 2000), this material would ideally be embedded within existing biotechnology units and taught in the context of the material delivered in these units. There was widespread recognition by the biotechnology lecturers in this case study that delivery of science communication in this form would be preferable. But the lecturers also acknowledge this ideal would be difficult to achieve, since there is little room in the curriculum for new material. Science communication training would need to be given a higher priority for inclusion than it is currently afforded.

Moving science communication training from being an optional elective to a compulsory component of biotechnology education will ensure that all undergraduate biotechnology students are taught how to communicate with the public. At the postgraduate level, the supervisors of biotechnology research students would also need to be supported in their science communication mentoring capacity. Over time, the provision of training in this area may help change views of science communication and students may also be better placed to appreciate the importance of this training, particularly if lecturers, supervisors and curriculum planners in the program are seen to value science communication by supporting the delivery of materials in this area.

Lessons in how science communication may be integrated into the biotechnology curriculum may be learnt from the analysis of biotechnology programs that have included ethics studies into the curriculum (Stern & Elliot, 1997). In recent years, ethics has become part of many tertiary biotechnology curricula in response to calls for the inclusion of courses in research and professional ethics in tertiary science education (Lysaght, Rosenberger, & Kerridge, 2006). While there is significant variation in the extent and content of ethics education provided to students in different institutions, there is gradual recognition of the importance of incorporating ethics into biotechnology degrees. Employers support the provision of ethics education and undergraduate students generally regard ethics education to be important.

8.2 Repositioning Biotechnology Within the Sphere of Culture – the Content of Science Communication Courses aimed at Cultivating Civic Biotechnologists

Once there is clear support for the delivery of science communication training within the biotechnology curriculum, the next consideration will need to be what the content of this training should be. It will need to encompass scientist-to-scientist communication skills, the generic communication skills required by employers, and an awareness of civic science and skills in public engagement. At present, the

biotechnology program in the case study provides limited scientist-to-scientist communication skills (predominantly aimed at strengthening the students' capacity for report writing) and generic communication skills are delivered as part of the university-wide Generic Attribute program. The results of the present study, and surveys of science and biotechnology graduates, suggest the skills training in both of these areas need to be strengthened. Of prime importance, however, will be the inclusion of civic science training within the degree program. Until these biotechnology students are provided with the science communication training required to enable them to act as willing and able civic scientists, it is likely that biotechnology will continue to see itself as external to society and unable to reposition itself within this sphere.

In 1988 in a review of public understanding of science research, the UK's *Coalition for the Public Understanding of Science* (COPUS) stated that "the basic rules for communicating about scientific subjects are really the same as those for communicating in general (COPUS, 1998, p. 10). Today however there is widespread recognition that training scientists to be civic scientists requires more than the provision of a toolkit of scientist-to-scientist communication skills or a set of generic communication skills. The Royal Society (2005, p. 16) states "there are issues that are not resolved simply by skills training". As the aim of public engagement is not only to communicate clearly, but to improve the public understanding, public awareness, and scientific literacy of the community, scientists require an understanding and appreciation of civic science and its aims, an awareness of the repertoire of means available to achieve these aims, an appreciation of the distinction between civic science and scientist-to-scientist communication. An understanding of the legitimacy of the public voice in dialogue about science is also paramount. What one science communication lecturer describes as "nuts and bolts" training, will not provide students with this understanding. Clearly, in addition to strengthening the generic skills training and scientist-to-scientist training the students receive, these students will also require specialised civic science training.

As studies have shown that scientists who participate in civic science activities are more positively disposed to public engagement, a practical component may also be beneficial. In the present study, civic science experience did appear to have a positive influence on both the provision of science communication training, participation in science communication activities and recognition of the value of science communication. The lecturers who indicated they had experience in communicating with non-scientists were more likely to provide science communication training of this nature to their students, albeit informally. The early-career biotechnologists provided with some form of science communication training were more likely to engage in science communication activities with the public and report feeling better equipped to communicate the technical, and also the social and ethical implications of their research.

Only two of the doctoral students interviewed reported participating in activities involving communication with non-scientists. Both of these students, however, indicated an appreciation of the importance of civic science. It is difficult to determine from these results whether these students' experience with public engagement positively influenced their views of public engagement, or if the students were positively predisposed to engagement prior to participation. However a strong positive correlation has been observed between the number of science communication activities undertaken by scientists and their perception of the importance of public engagement (Royal Society, 2006b). If experience is shown to positively influence views towards public engagement, this suggests the science communication training at the postgraduate level may benefit greatly by the inclusion of a practical component, whereby students are given the opportunity to apply their communication knowledge and skills and participate in an activity involving public engagement.

Many of the participants in the case study spoke of the need to effect a grass roots change in thinking about science communication and civic science before this area can be introduced into the science curriculum. While the Royal Society suggests that the recent increased participation in science communication by scientists is indicative

of a cultural change towards greater acceptance of a civic science responsibility (Royal Society, 2005) others suggest scientists have yet to embrace science communication "in any systematic way" (Greco, 2006). Undoubtedly, as acknowledged by one of the science communication lecturers in the present study, there is likely to be a lag between science communication research and the cultural shift in scientists' thinking about science communication that researchers and policy makers now suggest is required. The science communication profession is in its infancy and there has been little research directed towards scientists' views of public engagement, and even less research directed towards science communication training. The Royal Society (Royal Society, 2006b) has recently recommended a review of public engagement training at the tertiary level and the expansion of training courses to include the skills required for public engagement.

While the calls for dialogue between scientists and the public are widespread, research and policy relating to public engagement is still being developed. As a consequence, dissemination of best practice for the delivery of the required knowledge and skills required for public engagement for undergraduate and postgraduate students has yet to occur. In the present study, the students' and lecturers' lack of understanding of science communication may reflect the fact that there has yet to be a cultural shift towards support for increased dialogue between scientists and the public. In the present case study, recent calls for greater involvement of scientists in public dialogue, graduates who are better trained in communication, and reviews of public engagement training at the undergraduate and postgraduate level, have not have translated yet into the generation of biotechnology students who support public engagement or biotechnology lecturers with a good understanding of science communication training.

Further research is clearly required to determine how barriers to science communication can be overcome, particularly, how biotechnology lecturers can be assisted in developing their understanding of this area and what is required to support them in the delivery of material that will foster public engagement in their area of science. Future research will need to consider how undergraduate students' and

lecturers' views will impact on the choice of teaching material and its delivery, and how supervisors can be supported in their mentoring of postgraduate research students with respect to public engagement, and evaluation of science communication teaching resources. In particular, research will need to address the undergraduates and postgraduate students' perception of the value of communicating with non-scientists and how receptive these students' will be to learning these skills. Given the results of the present study also suggest that science communication training will need to encompass both the skills required for scientist-to-scientist communication and public engagement, how these two distinct forms of communication training are linked together may also need to be considered.

Once innovative professional development approaches and teaching practices in this area are developed, effective means of disseminating this information will need to be determined and promoted. If the outcomes of further research in this area are made accessible to these stakeholder groups, it may only be a "matter of time" (as indicated by some in the case study) before best practice in science communication, and civic science in particular, becomes an integral component of tertiary biotechnology training.

8.3 Best Practice Recommendations

According to Keeves "the ultimate purpose of any kind of knowledge arrived at in educational research is to provide a basis for action, be it policy, action, or methods of teaching in the classroom" (Keeves, 1997). The following recommendations represent the key purpose of the present case study – a basis for facilitating the inclusion of civic science training within the biotechnology program. It is hoped that these recommendations in conjunction with ongoing research in this area will usefully inform those involved in the development of science communication training for tertiary biotechnology students. Ultimately this may lead to a new generation of biotechnology graduates able to constructively engage the public in discussion about their science. It is also hoped the results of this study will be

transferable to those involved in the development of science communication training in other areas of science as they develop new and potentially contentious technologies.

Recommendation 1: Existing science communication training for biotechnology students should be strengthened.

Science communication training in this case currently centres on report writing and generic communication skills training. Reform in this area should aim to strengthen these forms of communication training to meet employers' and the biotechnology professions expectations of the communication skills required of a biotechnology graduate.

Recommendation 2: Civic science training should be included as a component of science communication training.

In addition to strengthening biotechnology students scientist-to-scientist training and generic skills training, the students' awareness and understanding of civic science should also be developed. This civic science training will need to correct the perception that science communication fills a deficit in the public understanding of science. Students will need to appreciate that science communication involves dialogue positioned in the wider social context in which other forms of expertise may be legitimate. While an appreciation of the importance of civic science is the primary purpose of this training, civic science skills training will also be required that enables all biotechnology graduates to actively engage the public in dialogue about their research.

Recommendation 3: Science communication training should be compulsory.

The views of students and lecturers towards science communication training suggests the students do not value this form of training and the inclusion of non-compulsory courses in science communication may not reach students who enter mainstream research areas. Until there is a cultural shift in science towards strong support for civic science that is translated to a shift in students' appreciation of the value of science communication training, science communication may need to be mandated through the inclusion of compulsory, assessed material in this area.

Recommendation 4. Practical support for the delivery of science communication training is required.

While there is strong support for the delivery of science communication training in context in existing biotechnology units, lecturers will need to be provided with practical supports such as teaching materials and professional development to enable them to feel sufficiently comfortable with this area to incorporate it into their teaching practice. Teaching materials, in particular, will need to be made accessible to biotechnology lecturers. As research-based evidence for best-practice in science communication is generated, this will also need to be promoted to the lecturers and research supervisors who will deliver this training.

Recommendation 5: Inclusion of new science communication material into the biotechnology curriculum will likely require some existing material to be removed.

The perception that the biotechnology curriculum is overcrowded is a constraining factor will need to be overcome if new material is to be introduced in to the biotechnology program. Space will need to be made in the biotechnology curriculum for the inclusion of science communication training, most probably through the replacement of existing content. Individual lecturers who express an interest in science communication and are motivated to deliver science communication training

within their units will need to be cultivated to provide a ground swell of support for this reform of the program.

Recommendation 6. Negative perceptions of science communication and science communication training will need to be addressed.

There is evidence that science communication is not seen as a valued activity by the undergraduate biotechnology lecturers and research student supervisors. Biotechnology lecturers will need to impress upon the undergraduate students the value of science communication and provide greater recognition of where and when these skills are taught to enable the students to appreciate how their degree program values and provides them with these skills. Supervisors of postgraduate biotechnology students will need to encourage and support the civic science activities of their research students and provide sufficient guidance and feedback to enable the students to learn from their experiences. This is likely to require increased understanding and appreciation of the value of public engagement by the lecturers and supervisors. Science communication will need to be seen as an integral part of scientific practice and not as an *optional extra* or *soft* science, resulting in the inclusion of assessable science communication material in undergraduate units and improved mentoring in science communication by research supervisors. Public engagement about the social and ethical implications of research will need to be given as much legitimacy as the communication of the technical details of research.

Recommendation 7. Science communication will need to adapt to the changing nature of science.

As scientific research becomes increasingly influenced by commercial interests, science communication training will need to adapt accordingly. Considerations of intellectual property rights, commercial confidentiality and security will need to be balanced with public interest in research. In the future, science communication

training will need to adapt to other factors constraining public engagement as they emerge.

8.4 Conclusion

As the world economies continue to advance and transform into knowledge-based economies, the management of the relationship between society and emerging technologies such as biotechnology and the converging technologies of the future, will become increasingly important. Biotechnology programs will need to take into account possible convergence with other technologies, the changing nature of science, the changing nature of work, and the changing nature of public involvement in science.

It is hoped the results of the present case study may contribute to more effective management of the relationship between society, biotechnology, and ultimately other emerging technologies, by promoting the civic science capacity of biotechnologists. By highlighting the need for compulsory science communication training for biotechnology students, it is hoped that these recommendations will be incorporated into science curricula, and future generations of students will enter the industry as able communicators that are appreciative and receptive to the role the public increasingly plays in shaping emerging technologies.

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APPENDICES

Appendix 1.1 Interview Information Letter

Dear xxxx

I am a PhD student in Science Education in the School of Education at Edith Cowan University. I would like to invite you to be involved in a research study examining the role of science communication within tertiary biotechnology education. Specifically the aims of the study are to determine:

- What the 'actual' picture of science communication training for early-career biotechnologists is.
- What the 'ideal' picture of science communication training for early-career biotechnologists is.
- How the gap between the 'actual' and 'ideal' picture of science communication training for early-career biotechnologists can be reduced (in order to promote their development into civic scientists).

It is anticipated that the results of this study will inform current science education and lead the way to development of a model of best practice for science communication training of early-career biotechnologists. This research project has been approved by the ECU Human Research Ethics Committee.

As a postgraduate biotechnology student / biotechnology lecturer / supervisor of postgraduate biotechnology students / science communicator / science communication lecturer you are invited to participate in an audiotaped face-to-face interview of approximately 30 minutes duration.

All information provided will be confidential and no individuals will be identified. The audiotapes will be transcribed and any identifying information from interview transcripts will be removed and pseudonyms will be used in the analysis and dissemination of findings from the research. Audiotapes, paper transcripts and electronic files will be stored securely and destroyed five years after the completion of the study.

Any questions concerning the research study entitled *Cultivating the Civic Scientist: Science Communication & Tertiary Biotechnology Education* can be directed to Jo Edmondston on 0407 198 316 or her PhD supervisor Dr Vaille Dawson of the School of Education on 63045702. We are happy to discuss any questions you may have about the questionnaire or interview. If you have any concerns or complaints about the study or would like to talk to an independent person, you may contact the Research Ethics Officer, Kim Gifkins, at:

Human Research Ethics Office
Edith Cowan University
Joondalup WA 6027
Phone:(08) 6304 2170, Email:research.ethics@ecu.edu.au

Thank you very much for reading this information. If you agree to participate in this research study could you please sign the consent form supplied.

Regards

Jo Edmondston
PhD student in Science Education
Edith Cowan University

Appendix 2.1 Combined Consent Form and Information Letter for Undergraduate Biotechnology Students

Dear Student,

I am a PhD student in Science Education in the School of Education at Edith Cowan University. I would like to invite you to be involved in a research study examining the role of science communication within tertiary biotechnology education. Specifically the aims of the study are to determine:

- What the 'actual' picture of science communication training for early-career biotechnologists is.
- What the 'ideal' picture of science communication training for early-career biotechnologists is.
- -How the gap between the 'actual' and 'ideal' picture of science communication training for early-career biotechnologists can be reduced.

It is anticipated that the results of this study will inform current science education and lead the way to development of a model of best practice for science communication training of early-career biotechnologists. This research project has been approved by the ECU Human Research Ethics Committee.

As a biotechnology student you are invited to complete the enclosed questionnaire which will take approximately five minutes to complete. If you agree to be contacted at a later date by providing your contact details on the relevant section on the last page of the survey, you may be contacted for a follow-up audiotaped telephone interview of approximately 5-10 minutes duration.

All information provided will be confidential and no individuals will be identified. The audiotapes will be transcribed and any identifying information from interview transcripts will be removed and pseudonyms will be used in the analysis and dissemination of findings from the research. Questionnaire, audiotapes, paper transcripts and electronic files will be stored securely and destroyed five years after the completion of the study.

Any questions concerning the research study entitled *Cultivating the Civic Scientist: Science Communication & Tertiary Biotechnology Education* can be directed to Jo Edmondston on 0407 198 316 or her PhD supervisor Dr Vaille Dawson of the School of Education on 6304 5702. We are happy to discuss any questions you may have about the questionnaire or interview. If you have any concerns or complaints about the study or would like to talk to an independent person, you may contact the Research Ethics Officer, Kim Gifkins, at:

Human Research Ethics Office
Edith Cowan University
Joondalup WA 6027
Phone:(08) 6304 2170, Email:research.ethics@ecu.edu.au

Thank you very much for reading this information.

If you agree to participate in this research study could you please complete the questionnaire provided.

Regards

Jo Edmondston
PhD student in Science Education
Edith Cowan University

Appendix 2.2 Interview Consent Form

EDITH COWAN UNIVERSITY

CONSENT FORM

Study Title:
Cultivating the Civic Scientist: Science Communication & Tertiary Biotechnology Education

I have read and understood the information letter above that explains the research study. I have been given the opportunity to ask questions and have had any questions answered to my satisfaction. I understand that if I have any additional questions I can contact the research team whose contact details are included below. I understand that the information provided will be kept confidential, and that the identity of participants will not be disclosed without consent. I understand that the information provided will only be used for the purposes of this research project, and I understand how the information is to be used. I understand that I am free to withdraw from further participation in this study at any time, without explanation or penalty. I freely agree to participate in the project.

I agree to participate in a face-to-face interview that will take approximately 30 minutes to complete. The interview will be audio-taped and five years after the completion of the project the audiotape will be destroyed.

Participant Name:

Date:

Participant Signature:

Jo Edmondston
PhD student
School of Education
Faculty of Community Services, Education and Social Sciences
Edith Cowan University
Phone: 0407 198 316

Appendix 3.1 Interview Schedule Provided to Early-career Biotechnologists

The following questions have been provided to indicate the structure of the interview and the type of questions that may be asked. The format of the questions may vary in the interview and additional questions may be asked as the interview proceeds.

How successfully do you feel biotechnology is currently communicated to non-scientists?

What role do you feel biotechnologists should play in communicating biotechnology research and its social and ethical implications to the non-scientists?

Do you feel biotechnologists need to change their current approach to communicating their research and its social and ethical implications?

How equipped do you feel to communicate your research to the non-scientists

Have you been involved in any science communication activities or programs?

Do you feel the training and skills required for communicating research to non-scientists differ from those required for communicating with fellow scientists?

Do you think science communication training should be a component of tertiary education for biotechnology students?

Have you had any science communication training since graduating?

Where would you seek science communication training?

Have you discussed communicating your research and its social and ethical implications to the public, with your employer or any of your fellow researchers?

Appendix 3.2 Interview Schedule Provided to Lecturers

The following questions have been provided to indicate the structure of the interview and the type of questions that may be asked. The format of the questions may vary in the interview and additional questions may be asked as the interview proceeds.

How successfully do you feel biotechnology is currently communicated to non-scientists?

Do you provide any science communication training to undergraduate or postgraduate biotechnology students?

Are you aware of any units (or components of units) offered to undergraduate or postgraduate biotechnology students in science communication?

Do you feel science communication training should be a component of the undergraduate and/or postgraduate education of biotechnology students?

Do you think the generic communication skills training provided for postgraduate biotechnology students is sufficient to enable these graduates to perform a civic science role when they enter the biotechnology workforce?

Do you think science communication education is different from educating students to communicate with other scientists?

Are you aware of any organisational supports provided for the provision of science communication education at the undergraduate or postgraduate level?

Can you identify any organisational barriers to the provision of science communication education at the undergraduate or postgraduate level?

Are you aware of any supporting material for science communication education of undergraduate or postgraduate biotechnology students? (eg texts, websites, models of best practice teaching?)

Would it be feasible to introduce additional science communication educational components into the current biotechnology curriculum?

Appendix 3.3 Interview Schedules Provided to Science Communicators and Science Communication Lecturers

The following questions have been provided to indicate the structure of the interview and the type of questions that may be asked. The format of the questions may vary in the interview and additional questions may be asked as the interview proceeds.

How successfully do you feel biotechnology is currently communicated to non-scientists?

What role do you feel biotechnologists should play in communicating biotechnology research and its social and ethical implications to the non-scientists?

Do you feel biotechnologists need to change their current approach to communicating their research and its social and ethical implications?

Do you feel biotechnologists are sufficiently aware of the approaches they can or should take to science communication programs or activities?

Do you feel biotechnologists are sufficiently aware of where they can seek help for science communication when they undertake science communication programs or activities?

Do you feel the skills required for science communication with the non-scientists differ from those required for communicating with fellow scientists?

How important do you think science communication training is for early-career biotechnologists?

Should science communication education be a component of tertiary training for biotechnology students?

Have you had any experience in teaching science communication to scientists?

Do you have any views on the science communication education that biotechnologists currently receive as part of their tertiary training?

Are you aware of any material that can be used to support the provision of science communication education at the tertiary level? (eg texts, websites, models of best practice teaching?)

What do you think would be the outcome of improving the science communication training of early-career biotechnologists?

Appendix 4 Questionnaire

EDITH COWAN UNIVERSITY

Science Education – Jo Edmondston

QUESTIONNAIRE

This is an anonymous questionnaire. Please ensure that you do not write your name, or any other comments that will make you identifiable on the questionnaire. The attached Information Letter carefully as it explains fully the intention of the research project.

Please tick the correct box:

Are you ☐ Male ☐ Female

What program are you enrolled in?

☐ Biotechnology

☐ Other. Please state…………

Have you completed the unit *E398 Science Communication?*

☐ Yes

☐ No

Do you plan to enrol in the unit *E398 Science Communication?*

☐ Yes

☐ No

What does the term 'science communication' mean to you?

How important do you think it is that the non-scientists understand ......
Indicate your answer by marking a cross on the line.
Place a cross in the box next to the question if you don't know the answer.

...the technical aspects of biotechnology research?

Unimportant *Very important* *Don't know*

... the social and ethical implications of biotechnology research?

Unimportant *Very important* *Don't know*

How responsible should the following groups be for communicating the *technical aspects* of biotechnology research with non-scientists?
Indicate your answer by marking a cross on the line, or place a cross in the box.

Government
Not responsible *Very responsible* *Don't know* ☐

Journalists
Not responsible *Very responsible* *Don't know* ☐

Professional Science Communicators
Not responsible *Very responsible* *Don't know* ☐

Campaigning Groups (e.g. Greenpeace)
Not responsible *Very responsible* *Don't know* ☐

Biotechnologists
Not responsible *Very responsible* *Don't know* ☐

How responsible should the following groups be for communicating the *social and ethical implications* of biotechnology research with non-scientists?
Indicate your answer by marking a cross on the line, or place a cross in the box.

Government
Not responsible *Very responsible* *Don't know* ☐

Journalists
Not responsible *Very responsible* *Don't know* ☐

Professional Science Communicators
Not responsible *Very responsible* *Don't know* ☐

Campaigning Groups (e.g. Greenpeace)
Not responsible *Very responsible* *Don't know* ☐

Biotechnologists
Not responsible *Very responsible* *Don't know* ☐

How strongly do you agree or disagree with the following statements?
Indicate your answer by marking a cross on the line, or place a cross in the box.

Biotechnologists have a responsibility to communicate.....

...the technical aspects of their research with the non-scientists.

Strongly disagree ●————————● *Strongly agree* *Don't know* ☐

...the ethical and social implications of their research with non-scientists.

Strongly disagree ●————————● *Strongly agree* *Don't know* ☐

...their research and its implications with non-scientists, but only after peer review.

Strongly disagree ●————————● *Strongly agree* *Don't know* ☐

Science communication activities may impact on non-scientists in a number of ways. Indicate how you would rate the success of a science communication activity if it resulted in the following *responses by non-scientists?*
Indicate your answer by marking a cross on the line, or place a cross in the box.

Improved awareness of biotechnological products and processes.

Failure ●————————● *Success* *Don't know* ☐

Improved understanding of biotechnological products and processes.

Failure ●————————● *Success* *Don't know* ☐

Greater debate about biotechnological products and processes.

Failure ●————————● *Success* *Don't know* ☐

Greater acceptance of biotechnological products and processes.

Failure ●————————● *Success* *Don't know* ☐

How would you rate the importance of communicating the *technical aspects* of biotechnology research with the following groups?
Indicate your answer by marking a cross on the line, or place a cross in the box.

Biotechnologists
Unimportant ———————— *Very Important* *Don't know* ☐

Scientists other than biotechnologists
Unimportant ———————— *Very Important* *Don't know* ☐

Non-specialist public
Unimportant ———————— *Very Important* *Don't know* ☐

Managers of biotechnology industries
Unimportant ———————— *Very Important* *Don't know* ☐

Journalists
Unimportant ———————— *Very Important* *Don't know* ☐

Government
Unimportant ———————— *Very Important* *Don't know* ☐

How would you rate the importance of communicating the *social and ethical implications* of biotechnology research with the following groups?
Indicate your answer by marking a cross on the line, or place a cross in the box.

Biotechnologists
Unimportant ———————— *Very Important* *Don't know* ☐

Scientists other than biotechnologists
Unimportant ———————— *Very Important* *Don't know* ☐

Non-specialist public
Unimportant ———————— *Very Important* *Don't know* ☐

Managers of biotechnology industries
Unimportant ———————— *Very Important* *Don't know* ☐

Journalists
Unimportant ———————— *Very Important* *Don't know* ☐

Government
Unimportant ———————— *Very Important* *Don't know* ☐

How important do you think it is that the following items are included in the undergraduate biotechnology curriculum?
Indicate your answer by marking a cross on the line, or place a cross in the box.

A broad knowledge of general scientific facts and theories
Unimportant ——— *Very Important* *Don't know* ☐

Skills in communicating research with other scientists
Unimportant ——— *Very Important* *Don't know* ☐

Business and marketing skills
Unimportant ——— *Very Important* *Don't know* ☐

Technical skills (eg. lab work)
Unimportant ——— *Very Important* *Don't know* ☐

Data analysis skills (eg. statistical analysis)
Unimportant ——— *Very Important* *Don't know* ☐

An understanding of intellectual property and patenting issues
Unimportant ——— *Very Important* *Don't know* ☐

An understanding of animal ethics regulations and related issues
Unimportant ——— *Very Important* *Don't know* ☐

Skills in communicating research with non-scientists
Unimportant ——— *Very Important* *Don't know* ☐

An understanding of human ethics regulations and related issues
Unimportant ——— *Very Important* *Don't know* ☐

An appreciation of what constitutes scientific misconduct
Unimportant ——— *Very Important* *Don't know* ☐

Knowledge of the specific facts and theories related to biotechnology
Unimportant ——— *Very Important* *Don't know* ☐

An awareness of the public's perception of the risks associated with research and research outcomes
Unimportant ——— *Very Important* *Don't know* ☐

Have you have received any training in how to communicate the *technical aspects* of biotechnology research with the non-scientists, at any stage of your degree program?

☐ No

☐ Yes. Please indicate:

(i) which units this training was provided in, and

(ii) the type of training provided.

Have you have received any training in how to communicate the *social and ethical implications* of biotechnology research with the non-scientists, at any stage of your degree program?

☐ No

☐ Yes. Please indicate:

(i) which units this training was provided in, and

(ii) the type of training provided.

Thankyou for completing this questionnaire

Appendix 5 Shortened Questionnaire

EDITH COWAN UNIVERSITY

Science Education – Jo Edmondston
QUESTIONNAIRE

This is an anonymous questionnaire. Please ensure that you do not write your name, or any other comments that will make you identifiable on the questionnaire. The attached Information Letter carefully as it explains fully the intention of the research project.

Please tick the correct box:

Are you ☐ Male ☐ Female

What program are you enrolled in? ☐ Biotechnology

☐ Other. Please state...........

Have you completed the unit *E398 Science Communication?*

☐ Yes

☐ No

Do you plan to enrol in the unit *E398 Science Communication?*

☐ Yes

☐ No

How important do you think it is that the following items are included in the undergraduate biotechnology curriculum?
Indicate your answer by marking a cross on the line, or place a cross in the box.

A broad knowledge of general scientific facts and theories
Unimportant ●————● *Very Important* — *Don't know* ☐

Skills in communicating research with other scientists
Unimportant ●————● *Very Important* — *Don't know* ☐

Business and marketing skills
Unimportant ●————● *Very Important* — *Don't know* ☐

Technical skills (eg. lab work)
Unimportant ●————● *Very Important* — *Don't know* ☐

Data analysis skills (eg. statistical analysis)
Unimportant ●————● *Very Important* — *Don't know* ☐

An understanding of intellectual property and patenting issues
Unimportant ●————● *Very Important* — *Don't know* ☐

An understanding of animal ethics regulations and related issues
Unimportant ●————● *Very Important* — *Don't know* ☐

Skills in communicating research with non-scientists
Unimportant ●————● *Very Important* — *Don't know* ☐

An understanding of human ethics regulations and related issues
Unimportant ●————● *Very Important* — *Don't know* ☐

An appreciation of what constitutes scientific misconduct
Unimportant ●————● *Very Important* — *Don't know* ☐

Knowledge of the specific facts and theories related to biotechnology
Unimportant ●————● *Very Important* — *Don't know* ☐

An awareness of the public's perception of the risks associated with research and research outcomes
Unimportant ●————● *Very Important* — *Don't know* ☐

Thankyou for completing this questionnaire

Appendix 6 Interview Schedule for Pilot of Questionnaire

Date: Wednesday Sept 21

Note time taken to complete questionnaire.

Format of the questionnaire

Did you find the questionnaire format easy to follow?

Did you understand the instructions for how to respond to the questions?

Understanding of the question content

Do you understand the questions?

Did you feel there were any ambiguous questions?

Did you feel there were any leading questions?

Were there any questions you felt unwilling to answer?

Were you able to answer the questions?

Were any of the questions repetitive?

Specific Questions

What do understand the term 'non-specialist public' to mean?

What do understand the term 'technical aspects' to mean?

What do understand the term 'social and ethical implications' to mean?

Can you give an example for each one of the groups listed?

What do understand the term 'peer review' to mean?

What do understand the term 'improved understanding' to mean?

What do understand the term 'improved awareness' to mean?

What do understand the term 'greater debate' to mean?

What do understand the term 'greater acceptance' to mean?

Can you give an example for each one of the groups listed?

What do you understand 'training' to comprise in this question?

Is the first question difficult to answer?

Appendix 7.1 Undergraduate Interview Schedule

Number interviewed in group:
Name(s):
Date:
Location:
Interview Start:
Interview Finish:

What does the term 'science communication' mean to you?

How important do you think it is that non-scientists understand biotechnology?

How responsible should biotechnologists be for communicating biotechnology with non-scientists?

Science communication activities may impact on non-scientists in a number of ways. How you would rate the success of a science communication activity?

How would you rate the importance of communicating biotechnology research to non-scientists?

How important do you think it is that 'skills in communicating research with other scientists' is included in the undergraduate biotechnology curriculum?

How important do you think it is that 'skills in communicating research with non-scientists?' is included in the undergraduate biotechnology curriculum?

Have you have received any training in how to communicate biotechnology to the non-scientists, at any stage of your degree program?

Are you aware of the elective science communication unit?

Do you plan to enrol in the science communication unit?

Post Interview Comments:

Appendix 7.2 Doctoral Students' Interview Schedule

Name:
Date:
Location:
Interview Start:
Interview Finish:

Read the definition of *science communication* provided. Is this what science communication means to you?

Read the definition of *civic science* provided. Is this what civic science means to you?

Discuss both terms and ensure shared understanding (especially the way in which these terms are operationalised in this study) before proceeding further with interview.

Please describe your doctoral research project.

When do you anticipate you will submit your thesis for examination?

Have you been involved in any science communication activities?

If yes - Please describe these activities.

Did you seek any help for these activities? If so, what help did you seek?

Have you discussed communicating your research with non-scientists with your supervisor?
Have you discussed communicating the social and ethical implications of your research with non-scientists with your supervisor?

Please comment on any science communication training you received during your undergraduate training?

Describe any science communication training you have had as part of your postgraduate training?

Do you feel this training prepared you for a science communication role?

Have you completed the generic skills training course offered to all postgraduate students? Students are shown the course flyer.

If no – Do you plan to enrol in any of the modules of this course?

Do you plan to enrol in the communication skills course?

Has your supervisor encouraged you to enrol in this communication skills course?

Do you feel you have time to attend this generic communication skills training course?

How important a part of postgraduate training do you think the generic communication skills training course is?

Do you think this course should be compulsory?

Post Interview Comments:

Appendix 7.3 Early-career Biotechnologist Interview Schedule

Name:
Date:
Location:
Interview Start:
Interview Finish:

Read the definition of *science communication* provided. Is this what science communication means to you?

Read the definition of *civic science* provided. Is this what civic science means to you?

Discuss both terms and ensure shared understanding (especially the way in which these terms are operationalised in this study) before proceeding further with interview.

Please describe your current position of employment.

How many years ago did you graduate from the biotechnology program?

Do you have any postgraduate qualifications?

Have you been involved in any science communication activities?

If yes - Please describe these activities.

Did you seek any help for these activities? If yes, please describe.

Please describe any science communication training you received during your undergraduate training?

Please describe any science communication training you received during your postgraduate training?

Did you complete the generic skills training course offered to postgraduate students? Students are shown the course flyer.

Have you had any science communication training since graduating?

If yes - please describe.

If no - Where would you seek science communication training?

How equipped do you feel to communicate the *technical details* of your research to non-scientists?

How equipped do you feel to communicate the *ethical and social implications* of your research to non-scientists?

How successfully do you feel biotechnology is currently communicated to non-scientists?

What role do you feel biotechnologists should play in communicating the *technical details* of biotechnology research to non-scientists?

If not, who should be responsible?

What role do you feel biotechnologists should play in communicating the *social and ethical implications* of biotechnology research to non-scientists?

If not, who should be responsible?

Do you feel *early career biotechnologists* should play a role in communicating the technical details, and the social and ethical implications, of biotechnology research with non-scientists?

Do you feel biotechnologists need to change their current approach to communicating their research and its social and ethical implications?

If yes – why?

What changes need to be made?

Should science communication education be a component of tertiary training for biotechnology students?

If yes, at what level do you think this training should be provided?

Undergraduate / Postgraduate/Both?

Do you think the science communication capacity of biotechnologists can be improved by science communication training?

Have you discussed communicating the technical details of your research with non-scientists with your employer or fellow employees?

Have you discussed communicating the social and ethical implications of your research with non-scientists with your employer or fellow employees?

Post Interview Comments:

Appendix 7.4 Lecturer Interview Schedule

Name:
Date:
Location:
Interview Start:
Interview Finish:

What is your current position within the university?

How many years have you been employed as a lecturer at this university?

How many years have you been an academic?

What was your background prior to this position?

Please describe any experience you have had in science communication.

Read the definition of *science communication* provided. Is this what science communication means to you?

Read the definition of *civic science* provided. Is this what civic science means to you?

Discuss both terms and ensure shared understanding (especially the way in which these terms are operationalised in this study) before proceeding further with interview.

Do you provide any science communication training to undergraduate or postgraduate biotechnology students?

Are you aware of any units (or components of units) offered to undergraduate or postgraduate biotechnology students in science communication?

How successfully do you feel biotechnology is currently communicated to non-scientists?

What role do you feel biotechnologists should play in communicating the *technical details* of biotechnology research to non-scientists?

If not, who should be responsible?

What role do you feel biotechnologists should play in communicating the *social and ethical implications* of biotechnology research to non-scientists?

If not, who should be responsible?

Do you feel *early career biotechnologists* should play a role in communicating the technical details, and the social and ethical implications, of biotechnology research with non-scientists?

Do you feel biotechnologists need to change their current approach to communicating their research and its social and ethical implications?

If yes – why?

What changes need to be made?

Do you feel science communication training should be a component of the undergraduate and/or postgraduate education of biotechnology students?

If yes – compulsory or elective? stand alone unit or embedded?

How would you rate your ability to teach science communication?

Do you feel early career biotechnologists require science communication training?

If yes – who should provide this training?

Do you feel the skills required for communicating research to non-scientists differ from those required for communicating with fellow scientists?

Are you aware of any supports provided for the provision of science communication education at the undergraduate or postgraduate level?

If no – Are you aware of any *material supports* for the provision of science communication education at the undergraduate or postgraduate level?

Such as texts, websites, models of best practice teaching?

If yes, for texts – How appropriate are these for teaching biotechnology students?

Can you identify any barriers to the provision of science communication education at the undergraduate or postgraduate level?

If yes - How do you think these barriers could be overcome?

Would it be feasible to introduce science communication training into the current biotechnology curriculum?

What do you think would be the outcome of improving the science communication training of early-career biotechnologists?

Post Interview Comments:

Appendix 7.5 Science Communicator & Science Communication Lecturer Interview Schedule

Name:
Date:
Location:
Interview Start:
Interview Finish:

Please describe your current position of employment.
Please describe your background.

Read the definition of *science communication* provided. Is this what science communication means to you?
Read the definition of *civic science* provided. Is this what civic science means to you?
Discuss both terms and ensure shared understanding (especially the way in which these terms are operationalised in this study) before proceeding further with interview.

How would describe the science communication education that biotechnologists currently receive as part of their tertiary training?

Science communicators : Do you have any experience in teaching science communication to scientists?
Science communication lecturers: Please describe your science communication lecturing experience.

How successfully do you feel biotechnology is currently communicated to non-scientists?

What role do you feel biotechnologists should play in communicating the *technical details* of biotechnology research to non-scientists?

If not, who should be responsible?

What role do you feel biotechnologists should play in communicating the *social and ethical implications* of biotechnology research to non-scientists?

If not, who should be responsible?

Do you feel *early career biotechnologists* should play a role in communicating the technical details, and the social and ethical implications, of biotechnology research with non-scientists?

If yes - How important do you think science communication skills are for early-career biotechnologists?

Do you feel biotechnologists need to change their current approach to communicating their research and its social and ethical implications?

If yes – why?

What changes need to be made?

How equipped do you feel early career biotechnologists are to communicate the technical details of their research to non-scientists?

How equipped do you feel career biotechnologists are to communicate the ethical and social implications of their research to non-scientists?

Do you feel biotechnologists are sufficiently aware of the approaches they can or should take to science communication programs or activities?

Do you feel *early career biotechnologists* are sufficiently aware of the approaches they can or should take to science communication programs or activities?

Do you feel biotechnologists are sufficiently aware of where they can seek help for science communication when they undertake science communication programs or activities?

Do you feel *early career biotechnologists* are sufficiently aware of where they can seek help for science communication when they undertake science communication programs or activities?

Do you feel science communication training should be a component of the undergraduate and/or postgraduate education of biotechnology students?

If yes – compulsory or elective? stand alone unit or embedded?

If no - Do you feel early career biotechnologists require science communication training? If yes – who should provide this training?

Are you aware of any supports provided for the provision of science communication education at the undergraduate or postgraduate level?

If no – Are you aware of any *material supports* for the provision of science communication education at the undergraduate or postgraduate level?
Such as texts, websites, models of best practice teaching?
If yes, for texts – How appropriate are these for teaching biotechnology students?

Can you identify any barriers to the provision of science communication education at the undergraduate or postgraduate level?

If yes - How do you think these barriers could be overcome?

What do you think would be the outcome of improving the science communication training of early-career biotechnologists?

Would it be feasible to introduce science communication training into the current biotechnology curriculum?

Do you think the science communication capacity of biotechnologists can be improved by science communication training?

Do you feel the skills required for biotechnologists to communicate their research with non-scientists differ from those required for communicating with fellow scientists?

Is generic communication skills training sufficient for training a biotechnologist to be a science communicator?

Post Interview Comments:

Appendix 8 Background Information

Background Information

Study Title: *Cultivating the Civic Scientist: Science Communication & Tertiary Biotechnology Education*

Researcher: *Joanne Edmondston*

The terms 'science communication' and 'civic scientists' will be used throughout the interview you have agreed to participate in. There are a range of understandings of these terms in the literature. For the purposes of this interview, these terms are defined as indicated below:

> *Science communication* may be defined as the processes by which scientific culture and knowledge become incorporated into the common culture.

> A *civic scientist* is a scientist who communicates with a range of audiences and brings knowledge and expertise about science into the public arena.

Appendix 9 NVivo Assisted Coding of Open Question in Questionnaire and Interview Transcripts

Have you been involved in any science communication activities or programs?
No
Yes - Activity description
Yes – communication with fellow scientists
Public not interested
Communication-ready research

Please comment on any science communication training you received during your undergraduate training?
None
Report writing
Oral presentation
Other

Describe any science communication training you have had as part of your postgraduate training?
None
Report writing
Oral presentation
Other

Have you completed the generic skills training course offered to all postgraduate students?
Yes
No

Have you had any science communication training since graduating?
No
Yes – activity description

Where would you seek science communication training?
Don't know
Supervisor
University
Other - description

How equipped do you feel to communicate your research?
Equipped
Not equipped

Equipped to communicate technical only

Have you discussed communicating your research and its social and ethical implications to the public, with your supervisor

Yes

No

Have you discussed communicating your research and its social and ethical implications to the public, with your employer or any of your fellow researchers.

Yes

No

Do you provide any science communication training to undergraduate or postgraduate biotechnology students?

No

Report writing

Oral presentation

Too much emphasis in curriculum on report writing

Other - description

Are you aware of any units (or components of units) offered to undergraduate or postgraduate biotechnology students in science communication?

Yes

No

Aware of Science communication unit

Reservations about science communication unit

How would describe the science communication education that biotechnologists currently receive as part of their tertiary training?

Insufficient

Sufficient

Spin

Oral presentation is sufficient

How equipped do you feel early career biotechnologists are to communicate the technical details of their research to non-scientists?

Equipped

Ill-equipped

Do you feel biotechnologists are sufficiently aware of the approaches they can or should take to science communication programs or activities?
Aware of approach
Unaware of approach
Deficit approach
The disconnected scientist
Soft science
Peer disdain
Real science

Do you feel biotechnologists are sufficiently aware of where they can seek help for science communication when they undertake science communication programs or activities?
Aware of sources of help
Unaware of sources of help

How successfully do you feel biotechnology is currently communicated to non-scientists?
Successful
Unsuccessful
Difficulty in defining biotechnology
Legends, myths, miscommunication, misunderstandings
Unbalanced coverage of biotechnology
Biotechnology should learn from prior mistakes made in science
Biotechnology is a special case

What role do you feel biotechnologists (and early career biotechnologists) should play in communicating biotechnology research and its social and ethical implications to the non-scientists?
Technical
Social and ethical
Early-career biotechnologists
Mandatory
Only the good communicators
Biotechnologists should use science communicators are intermediaries
Biotechnologists should self reflect on their practice
Science communication requires truth and honesty
Rogue traders who engage the public to the detriment of science
Science communication requires a human face
Biotechnology has made mistakes
Social and ethical implication is integral part of science
Contextualising science using social and ethical
Close to the community
Credibility of young researchers
Young researchers seen as partisan

Do you feel biotechnologists need to change their current approach to communicating their research and its social and ethical implications?
Technical aspects of research
Social and ethical implications
Suggestions for improvements
Accountability and funding
For improved understanding by public

Do you think science communication training should be a component of education of biotechnology students?
Yes
No
Elective
Compulsory
Stand-alone
Embedded
Science communication training for science communicators
Professional development in science communication
Advantages of multidisciplinarity in tertiary science education
Overcrowded biotechnology curriculum
Outcome of science communication training for tertiary science students?
Horses for courses – training only for scientists with an interest in science communication
Generational change required

Are you aware of any supports provided for the provision of science communication education at the undergraduate or postgraduate level?
Yes
No
Website material if search for it
Paucity of teaching materials
Development of own course readers

Can you identify any barriers to the provision of science communication education at the undergraduate or postgraduate level?
Yes
No
Overcrowded curriculum
Low priority for inclusion
Teaching expertise required
Students would not value training

Would it be feasible to introduce science communication training into the current biotechnology curriculum?

Yes

No

Time

Champion

Grassroots support

What do you think would be the outcome of improving the science communication training of early-career biotechnologists?

Improved communication skills of all scientists

Employment opportunities

Funding

Improved understanding of public

Transformation of biotechnology

Do you think the science communication capacity of biotechnologists can be improved by science communication training?

Yes

No

Do you feel the skills required for biotechnologists to communicate their research with non-scientists differ from those required for communicating with fellow scientists?

Yes

No

Truth

Laymans terms

Is generic communication skills training sufficient for training a biotechnologist to be a science communicator?

Yes

No

Relevance to science

Emergent themes across questions:
Spin and selling science
Soft science
Redefining science as civic science
Lessons to be learnt from introducing business skills into program
Ad hoc nature of current science communication training efforts
Science is nothing unless it is communicated
Science communication training should focus on understanding not skills

Science students don't like science communication
Commercialisation barriers to science communication
Preparing job ready graduates
Postgraduates should think and work independently

Appendix 10.1 Member Checking Covering Letter

Dear (insert name),

Thankyou for participating in an interview for my PhD project on (insert date). I have completed the initial analysis of the qualitative data I obtained from the transcript of our interview, and have included in this email a summation of the points that I may use in my thesis.

As the degree to which you agree with my summation of your interview comments is an important measure for my qualitative research, I would appreciate your feedback on my interpretation of your views on science communication and tertiary education.

I have also included in this email the direct quotes from your interview that I may reproduce in my thesis. They have been transcribed verbatim but may be edited prior to inclusion in my thesis to improve their clarity. I have included in italics above each quote the context in which I will use your quotes.

In addition to commenting on the interview summary I would also be grateful if you could answer the following questions:
(insert questions)

Your comments can be emailed to me by replying to this email at jedmonst@student.edu.au or sent to:
Jo Edmondston
Faculty of Community Services, Education and Social Sciences
School of Education
Joondalup Campus
Edith Cowan University
100 Joondalup Drive, Joondalup WA 6027

If you require a hard copy of this letter, the interview summation, quotes and questions, a complete transcript of you interview, and/or a pre-paid envelope, please email me and I will post these items to you.

If I do not hear from you before (insert date) I will presume you are in agreement with my summation of your interview comments.

Kind Regards,

Jo Edmondston
PhD Candidate
Science Education
Edith Cowan University

Appendix 10.2 Example 1 of Member Checking Summary – Linda, Early-career Biotechnologist

Summation of interview:

You feel biotechnology is a field that has significant relevance to the community. You feel non-scientists can benefit from the communication of biotechnology by improving their understanding, and thereby being able to distinguish speculation and controversy from the true nature.

You feel biotechnology has been generally well communicated with non-scientists but biotechnology is a broad field and some aspects have been communicated better than others. You feel forensic science, in particular, has had a high level of coverage in the media and in popular culture, but the provision of this large amount of forensic information has not translated into a better understanding of this area by non-scientists.

You feel there is always the capacity to improve science communication, and as biotechnology plays such an important role in society, and will play an increasingly important role, the communication will need to keep pace with the need for non-scientists to know more.

You feel all biotechnologists need to be aware of how to communicate their research, at the very least to be able to describe their research to a media representative. You feel early-career biotechnologists are the best resource for promoting the communication of biotechnology, and communicating biotechnology itself, to other early-career biotechnologists as the information the present is likely to be seen as relevant to individuals at a similar stage in their career.

You feel biotechnologists need to have a greater understanding of the media as a tool for improving scientific literacy, and younger researchers are increasingly recognising the importance of communicating with the media. You feel that

biotechnologists have a responsibility to communicate both the technical details of their work and the social and ethical implications.

You feel well equipped to communicate with non-scientists about biotechnology because you had had training and extensive experience and practice in science communication.

You feel the training and skills required for communicating research to the non-scientists differ significantly from those required for communicating with fellow scientists, particularly the level of detail you incorporate. You feel some scientists are so disconnected from non-scientists they may be unable to appreciate the level that communication needs to be pitched at for non-scientists.

You feel some scientists are naturally better at science communication than others, but every scientist can be trained to a minimum level in science communication skills. You feel that science communication training should be a compulsory component of the tertiary training of biotechnologists and this training should aim to give the students an appreciation of the importance of communication.

At the undergraduate level you feel the only science communication training you received was a requirement to give a number of oral presentations. You do not feel these presentations were a good training exercise as students could avoid participating if they did not want to present. You feel your employer is supportive of your communication activities, particularly as many of these promote the profile of your workplace.

Illustrative quotes:
Unless people actually know a bit about it you can get this horrible speculation and things can turn into something much bigger that it actually is or much worse than it really is. So it can get out of control. So I think people need to know enough about it and about the true nature of it so that they can understand what's going on in the world today.

In my area [forensic science] definitely it's communicated a lot but it's not really the kind of stuff that we actually do. So people know a lot about forensics but not necessarily what forensic science is about, so that's the other disadvantage if there's too much science communication. People think they know a lot about it but they don't really so, I guess, I think it's successful in getting it into the public psyche but, yeah, science is definitely there and forensic science in particular is very, very important and a very interesting area to work in so that's an advantage. You know, it gets people interested in it but then the actual understanding has to come from more than just the media and popular culture.

It's something that's not going to go away. It's a science that's going to keep going especially now and into the future from all kinds of applications for good and evil probably, so I think people need to know more and more about it and particularly the people who are communicating it need to know that.

We're the ones that can actually make that link with other new career scientists, I think, a lot better than the older researchers and that's what I've found anyway, when you're lecturing and stuff. I mean, they don't – you can be an expert in your field but trying to explain your field to someone who's got no idea what level of research you've been into, you know, sort of if we have the Nobel prize winner come and talk to us about their field of study you're like oh, that's really interesting but it's not relevant to me and so I think we're probably the best resource for trying to get other new career scientists aware of it.

Well, you can only pitch at what level you've got experience to. I mean, if I went in to give a lecture, like I have, I'm only telling them what my experience in the field was. I'm not, you know, trying to tell them that I've solved a thousand cases or anything like that. I'm just there to say well, you know, this is what I do every day and this is what you will be doing every day if you get out of, if you get out soon. I'm not – I don't think it's a valid criticism unless you are pretending to be something you're not.

I think they need to have a much deeper understanding of the tool of using the media because research is great, research is fabulous. But it doesn't mean anything unless you can actually make people understand what it's about. And I think, I think nowadays a lot of researchers are getting that, getting a lot better at it. But I'm sure there's still a lot of old school researchers who just think no, I'm here to do the work and write my results and things. And that's great but it's not going to make it valid to the world at large.

You can't just, you can't have that view and be a proper scientist, I think. You're just a lab rat if that's what you're doing.

I mean, you just have to be so conscious when you're talking to a non scientist of what they're going to read into what you say and that's, yeah, again something I think - because I'm not necessarily a research scientist – I've probably got a better understanding of how normal people would read into things because I'm not a boffin – lab rat.

I think some people are predisposed to being good at it but I, you know, to a certain level anyone can be trained in how to do it. It's a, yeah, it's a skill that you have to be trained in, I think.

I think every scientist has to realise that, you know, the importance of it. I don't necessarily think it has to be a big component but there has to be some level of understanding.

The people who really didn't want to do it, like you'd get in a group and then just be the one who sits at the back and changes the overheads.

Appendix 10.3 Example 1 of Member Checking Summary – Pierce, Lecturer

Summation of interview:

You have significant experience in communicating science with non-scientists. You have been involved with communication using the mass media, took on communication roles from an early stage in your career, and enjoy this process.

You see a role for early-career biotechnologists in science communication that involves communicating the technical as well as the social and ethical implications of research. You feel communicating with non-scientists about the social and ethical implications allows biotechnology to be contextualised and therefore, better understood by non-scientists. Communicating science may have reciprocal benefits for early-career biotechnologists as involvement in science communication may enable them to reflect on research and assess if they have a clear understanding of what they are doing. You feel science communication skills are important particularly important for biotechnologists because biotechnology is often a commercial enterprise and consequently biotechnologists are often required to 'sell science'.

You feel biotechnology is communicated poorly to non-scientists, which can be attributed in part to the complexity of defining what biotechnology is. You feel science communication comes naturally to some scientists, but those who do not have an innate skill in communication could become adept as science communication through the provision of science communication training.

You are aware of the undergraduate unit in science communication offered by the Division of Arts, and the generic skills training in communication offered to postgraduate students. As program chair of biotechnology you recommend the science communication unit as an elective, but find the uptake of this unit is very low. You think the generic communication skills training incorporated into the undergraduate curriculum emphasises written communication skills, in particular

report writing skills. Science communication training could focus more on oral communication skills.

You feel science communication training should be ideally included in the undergraduate curriculum, but do not teach any science communication content to undergraduate or postgraduate students. Ideally the training for students to communicate with fellow scientists would be embedded within existing units, and training how to communicate with non-scientists would be delivered in a stand-alone unit. Oral presentation skills would be emphasised as would how to prepare for communication. Postgraduate training in science communication training would centre on technical communication with other scientists.

You feel the provision of science communication training would reinforce the view that science communication is valued. It may generate early-career graduates who appreciate the importance of communicating and are more positively inclined towards communicating. In reality, however, science communication training is not a priority area for inclusion in the crowded biotechnology curriculum and it is not even high on the agenda of content for inclusion. There is very little flexibility in the biotechnology degree program for the inclusion of additional content.

You are not aware of any support for the provision of science communication training for undergraduate biotechnology students, but see the crowded curriculum as significant barrier. You are unaware of educational materials that support the provision of science communication training for science students. You do not feel you have the ability to teach science communication and would seek support from people with formal training in the area.

Illustrative quotes

I think people have difficulty getting their head around what biotechnology actually means, and maybe that's because it's a multi-disciplinary sort of science; it also obviously has the commercial aspects, the commerce aspects of marketing and management embedded in it as well. And so I think even the students that come into

biotechnology are often unclear as to what biotechnology actually is. And so when the scientists themselves – or the younger scientists we train to be biotechnologists - are not sure what a biotechnologist is. It's quite difficult to then communicate that to people who are non-scientists.

No, I think it has to be both and I think that's perhaps the best way to capture people's imagination about biotechnology. If you just present it as some sort of arcane new technology or whatever, I think it turns a lot of people off but if they can see the relevance of it to, you know, social things, to, you know, their particular lifestyle – how is it going to effect me – then it makes it more real.

Biotechnologists, if they're becoming true biotechnologists, are probably going to be working for biotechnology companies where they're going to be involved in the marketing of biotechnological products. And they will have to be probably communicating to potential investors in the company and essentially explaining to them why this product is worth supporting. So from that perspective I think the training is more important to biotechnologists than to quite a lot of other scientists.

If that communication training is done in such a way that really impresses upon the student that as a biotechnologist this is a very important function of the biotechnology is to be good communicators, and I would hope that would then become embedded in their psyche to such an extent that it would be part of their, part of their overall training.

Part and parcel of the semesterisation system that we have, where you're teaching some fairly complex units in a pretty short timeframe, and it's quite hard to actually embed that sort of stuff in there without reducing content. Now, maybe we're too, maybe we're too focussed on content. We get a little bit constrained by just how much flexibility we can build into a degree programme because of having to meet the requirements of core, double majors, triple majors and there are so many students who actually are demanding those sorts of combinations that you tend to sort of follow the market trend.

We had this review meeting – we've got the last review meeting next week – we had a whole range of priorities that we wanted to fit in there. Interestingly science communication wasn't one of them and a lot of those priorities have actually had to drop out because we just couldn't find space for them, so I think it's going to be difficult

I think the sooner that you get them thinking about science communication – and by that I tend to mean science communication to people who are non-scientists, I suppose so they can think about how [illegible]stil the science down in a way that is explicable to a layperson, the better. Because they soon discover whether they really understand the science that they're being taught. If you can't distil it down to something to explain to somebody who's not a scientist, that is a fairly good indication you don't really have a thorough understanding of it yourself. So I think that's a fairly important part of the training for young scientists.

Appendix 10.4 Example 1 of Member Checking Summary – Charles, Science Communication Lecturer

Summation of interview:

You feel biotechnology has been very poorly communicated with non-scientists and there is evidence to suggest that science communication is given very low priority by the key stakeholders in this process (policy-makers, scientists, promotions committees, and lecturers). You feel biotechnology students have a poor level of understanding and awareness of science communication, with the exception of students who have an interest is science technology policy or those who take elective units in the social sciences. You feel that the communication of biotechnology needs to be significantly improved, and this could be achieved by communication between the community and biotechnologists at all stages of the innovation process (as opposed to current practice were communication between biotechnologists and the community occur after product development and release).

You feel that biotechnologists (including early-career biotechnologists) have a crucial role to play in communicating biotechnology research with non-scientists, but their current communication efforts require significant improvement. When communicating the technical aspects of biotechnology research, scientists should present themselves as technical experts. They should also communicate the social and ethical aspects of their research, but present themselves as informed citizens. You feel biotechnologists' are disinterested in science communication and see it as a low value, low reward activity. Their approach is primitive and limited to communication with their peers or 'selling science' to the community.

You feel science communication is in part, an innate ability. You feel generic skills courses provide students with 'nuts and bolts' communication skills but do not equip them with the understanding, views or specific skills required for effective science communication. You feel that there are significant differences in the type of communication that occurs between scientists compared to the communication that

occurs between scientists and non-scientists and biotechnologists need to be aware of these differences.

You think that biotechnology students are not provided with any science communication training. Ideally you would ensure all early-career biotechnologists are provided with science communication training that aims to generate a two way dialogue between scientists and non-scientists. You feel the need is so great for science communication training of biotechnologists that you would include a compulsory unit in science communication in the undergraduate curriculum and further training for postgraduate biotechnology students. You are pessimistic, however, that training will be introduced into the biotechnology curriculum as you feel that science communication is not a valued activity.

You have significant experience in teaching science communication and are aware of the science communication resources available. You feel they are not particularly good, lack local content and require adaptation for effective use in an Australian context.

You feel science communication training of early-career biotechnologists would improve biotechnologists' views towards science communication, in particular, increased understanding of, and sensitivity towards, community views and concerns.

Illustrative Quotes:
Science communication is seen as an activity you undertake if you have time after you've done the important things and the important things are doing science.

It's got to be seen as an integral part. It's got to be seen not just as something you do if you have time or if someone has the interest.

I think the problem is with scientists and policymakers that have a very narrow view of innovation, they see the process as one of producing x, y or z - it might be a new vaccine, it might be new genetically modified food. What they've got to understand

is that people in the community have the right, and do, reject those things if they think there's a problem. So innovation – a key part of innovation - is explaining what you do to the community before the innovation hits the community. So as you're producing it you actually put time and effort into saying this has a lot of benefit, it has a downside, this is how we manage the downside. So by the time the product hits the market or the process hits the market, people have a much better understanding and they won't do what they did in Europe and reject, for example, genetically modified food. So what I'm saying is policymakers and scientists need to rethink the innovation process...... The radical shift that I would like to see is scientists, science under-graduates, scientists and technologists seeing innovation in its broader definition, which is, the community is actually a part of the process. The community isn't an add-on at the end.... Get them involved in the process all along the way, not produce a genetically modified food and say 'Why don't you accept this?' and then be surprised when they reject it.

Part of their job, I think, is to say to the community of course there's a downside, there is a risk but breathing is risky, crossing the road is risky, getting on an aeroplane is risky. We know that and what do we do? We manage the risk. Similarly the scientists in industry who are producing this novel product, this innovation, know this as well as anybody on earth, better than anybody on earth. And I think it's – they have to be part of a team who fronts up to community, fronts up to parliament and parliamentary enquiries and say 'Yes, of course, there's a risk with this product and this is what we've done about managing the risk'......I think they've got a very techno-science view of innovation which, I think, is not going to work in the twenty first century.

Industry has to see people, not just as consumers, but citizens.

I think the scientists saying 'our expertise is in the science and that's where it stops'.....I mean that clearly is nonsense. They have to be accountable. ....They certainly should be saying 'We are the technical experts....but I'm also a citizen, you know, and I see the implications'.

Science communication has got to be given some status by the supervisor of their doctorates or whatever, or their – if they're doing an undergraduate degree - by the people who lecture them. So I think if scientists can make the shift, then the science undergraduates will pick up 'ah this is an important activity'.

Well they need to take it seriously. I mean, the current approach to communication, I think, is let's try and find more effective ways of communicating with our colleagues - conferences and so on - let's see if we can tell the community what we're doing so they'll give us more money. So it's a very primitive view of communication.

They don't see it as a high status, high level activity. Doesn't bring many rewards so why do it? In fact, I think – I wouldn't be surprised if some regard it as a demeaning activity almost. A real scientist - like real men don't eat quiche – real scientists don't communicate with the unwashed.

That sort of level is technically based. In other words it's about how can I improve my communication? That's important - what I call nuts and bolts - but the nuts and bolts has to be put into some sort of context. In other words we need to understand why are they doing this, what's the point, why we do want to communicate with people? And they need to understand it's not just a matter of communicating to, it's also listening. What are the community concerns, are they real concerns, are they perceived concerns, and whichever they are they need to be tackled.

I think they certainly need training in skills so that they write better, more effectively, they speak better, more effectively, the listen more effectively. But more than that, as I said before, they need to understand the context. Why are we doing this? What's the point? And the point isn't so that people in the community might spend more on funding. They may well do and that might be a spin off but the primary reason is so that the community can be educated. They can be told about the developments. They can be given an opportunity to voice their concerns and those concerns can be tackled. So the skills are incredibly important, but they need to be put in context.

They must not assume that these are people who are ignorant. That's the most, the worst possible thing you can do, assume people are ignorant.

In a sense it's almost like you're going to a new country. If you go to a new country you make all the efforts you can to properly understand the language, the currency, the customs. And that's in a sense what you do when you talk to community groups. You're actually in a different country. You're no longer in the country of scientists or biotechnologists, people who don't have the background, they haven't spent seven years, ten years, twenty years working in this area.

I think it's even more important for the postgraduates because they are likely to be working in industry and therefore they need to understand the community in which they're operating. And the community in which they operate does have concerns about various biotechnology issues, whether its agricultural biotech or medical biotech and I suspect increasingly in environmental biotech..... I think it would be useful for them to meet a couple of hours a week for a term or a semester, in which they discuss with other people. So what they're getting is not one view - that's the supervisors view. But, so effectively I think a version of the science communication unit which the under-graduates did would be good but a higher level.....something sustainable – I think we've got to get away from this idea of a morning or half an hour is going to do it – it's not. They need to reflect on the issues and, you know, if they think this is a waste of time they need to actually, to say so - why are we doing this?

seeking, and it was expressed within the community by the whole school motto that developed in the course of the research period: "You care, We care".

Other authors have continued to remind members of the field that PSoC must be able to handle other dominant themes and broader contexts. Prilleltensky (2001) has already been referred to in this chapter. Whilst producing a helpful values-based praxis framework, not dissimilar to the ones developed and described in this research, it has also been noted that in an effort to raise concern about one aspect of community oriented social action (social justice), Prilleltensky seems to have missed another, equally important aspect (social compassion).

Another theme that has been recently introduced to considerations about PSoC, is that of adversity in the face of considering risk and resilience. Such a theme and model, as constructed by Sandler (2001) has been put forward to assist community psychologists to review the "mechanisms by which adversities, protective resources or interventions work, or how they are changed through preventive interventions" (p. 48). It could be suggested that such a framework is necessary because a dominance of the PSoC literature has been focussed on determining those factors that assist in its development, whilst ignoring factors destructive to PSoC. Unlike the frameworks depicted in this report, few researchers and theorists have attempted to simultaneously describe the positive (transformative) and negative (adversity creating) conditions of PSoC, and the interactions between them.

The conceptualising of these mechanisms has been addressed by such authors as Maton (2000), whose work was used to help analyse the focus group interviews over time (Chapter 5). O'Donnell, Tharp, and Wilson's (1999) work on activity settings has been incorporated into the construction of the key frameworks of this research, in recognition that they are the basic units of "conceptualised human activity" whereby the important variables are "relationships, because the heart of an activity setting is human interaction" (pp. 504, 505). This concept of 'intersubjectivity' has not had much response in subsequent PSoC articles, but is a reminder that the relationships in which PSoC is developed are central to unity or disparity, and are evident through the dialogue of the persons in relationship. The mapping of intersubjectivity within activity settings is something that could be added more explicitly in the kind of research

undertaken here. This would be in line with Cronick (2002) who linked conceptions of life world, linguistic representations and intersubjectivity to suggest that : "One way of innovating new realities is to create new environments. When a new school is established… then a new basis for subjectivity is prepared" (p. 536). This is what this research has been describing.

Another dimension that could have been included in this research is the multi-level modelling of Hughey, Speer, and Peterson (1999). In their construct, the authors reminded community psychologists that communities are in turn embedded into larger communities, in the same way that sub-groups make up the membership of any community as defined by the common membership vision of that collective. In this way, the community relates to other communities in four ways similar to that used in this research to portray individuals relating to a community.

Thus, instead of discreet units within larger contexts, (as exemplified by Maton, 2000), one could take the core of the community framework and represent it within a comparative, yet larger context. Figure 10 illustrates this principle. Each triangle represents a unit of human interaction within an activity setting, and represents the core constructs of vision, ethos, pathos, and connectedness. Each unit is given meaning by the descriptors of the community referenced social regularities. In this illustration, the large triangle (connectedness 1) represents the students' whole school PSoC experience. Triangle 2 represents the sub-group of the students' class within this experience, and it too can be represented with reference to the PSoC experience re commitment and alienation. The same could be generated for other sub-groups to whom the student is attached – for example, his or her peer group (triangle 3), and family (triangle 4).

The large triangle could then be nestled within larger contexts – the group of independent schools; all the schools of the State; etc. This then could represent what Hughey et al. (1999) noted: "The core values of PSoC will emerge as individuals come to expect their interests are only realised among others" (p. 109). Thus, multi-level analysis is represented without losing the core descriptors of PSoC. Tseng et al. (2002) promoted such approaches that help keep social change strategies focussed on the dynamic processes within systems, rather than on outcomes within individuals. Brodsky, Loomis and Marx (2000)

also reflected similarly on the need to recognise that people were members of multiple communities, and thus interacted with "multiple *senses* [sic] of community" (p. 321). They developed two-dimensional models to describe this PSoC interaction.

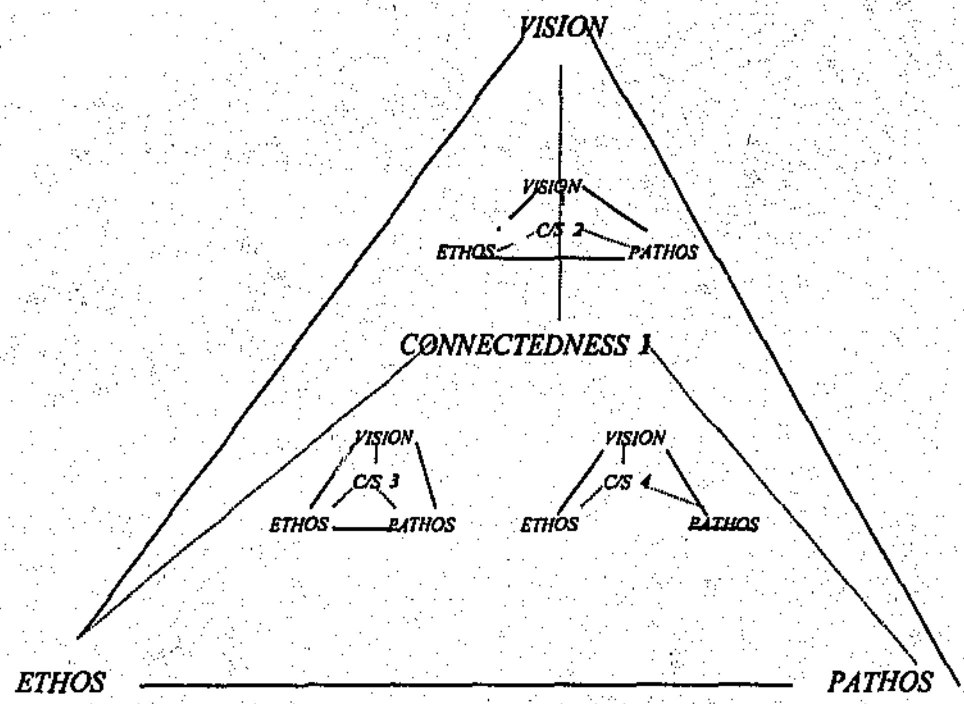

Figure 10. PSoC within community

If such a construct was employed, this research could have explored the students', parents' and staff member's understandings of how their belongingness at one level had an impact on their membership of that level. The students' discourse had some aspects of this emerge (i.e. coming to school for friends more than for classes), but it was not systematically explored, as suggested by this last framework. Such work is thus left for another time.

Two last references will be referred to in this review of the outcomes of Objective 3. This section has been reviewing the broadening scope of community psychology. The author suggests that there is one more field that has not been systematically explored conceptually or in practise. It is the area of creativity and change. Sarason referred to it in his autobiography (1988) and in one of his later writings on the preparation of teachers (as 'performing artists', 1999a). However, community psychology may need to consider more carefully

the realm of the "world 3" (Eccles, 1987, p. 91) level of human thinking to understand further the process of creative change within communities. Davies (1989) draws on the work of Eccles and Polanyi to delve into the relationship between the physical world, the transcendent world and the resulting creativity between the two. He noted:

> But again, once it is recognised that life transcends physics and chemistry, there is no reason for suspending recognition to the obvious fact that consciousness is a principle that fundamentally transcends not only physics and chemistry but also the mechanistic principles of living things (p. 194)

Davies explained that physics has developed the notion of 'quantum' leaps, and has observed apparent order from chaos. Perhaps community psychology also has to think about the meaning that persons in relationships can derive in the face of adversity, which can be defined as relational chaos. Such a start in considering the non-physical aspects of life may lead us to greater acts of integration, or community based tacit knowing (Grene, 1969).

This construct involves understanding the difference between what alienates us in how we approach things. To look *at* something is to externalise or alienate it. In contrast to this, we "endow a thing with meaning by interiorising it" (Grene, 1969, p. 146). This takes us back to our starting point of this research, which was how to understand (create meaning from) student's experiences in an innovative school reform, with reference to its implications for PSoC. The proposition was to travel with them, to hear and internalise their often-unheard voice, over 3 years.

This search for understanding, within a world that is both transcendent and rational, is not a new concern. The last reference in this chapter belongs to a researcher who analysed a teacher of teachers who lived over 1500 years ago. Howie (1969) recorded the following as one of Augustine's contributions to education:

> ...he declared that wisdom... is the ultimate goal of education. Wisdom is a higher value than science, the former being 'the intellectual understanding of eternal [transcendent] things', and the latter the 'rational understanding of temporal things'. Therefore, as educators [and community psychologists] we must maintain a sense of proportion. (p. 27)

CHAPTER 8 - CONCLUSION

In attempting to describe the life-worlds of students involved in an innovative middle school restructure, with reference to what was happening for them in their PSoC, the author committed himself to being a resident researcher for 5 years. During this time, 33 focus groups with 120 students were used to gather recorded interviews that were structured around critical community referenced and discourse sensitive questions.

These students were chosen because the issue of substance being investigated was that of alienation. It was demonstrated as being an issue of substance in the literature about emerging adolescents in schools, and through the practical experience of the author. The theoretical models were designed to see how readily this construct could be mapped as the antithesis of increasing sense of community.

The qualitative focus for the methodology was chosen because very little work had been done in Australia to hear the deeper text of the voices most effected by the transition from primary to secondary schooling. No work had been found describing this perspective with systematic reference to psychological sense of community – that is, from a community psychology perspective.

Over the two years of informal research and the three years of the formal research, there was gathered considerable complementary data to the interview data that enabled triangulation of the key concepts that were being developed. This involved the analysis, through grounded theory, of about 400 surveys (approx. 300 student and 100 adult) over the five-year period. There were also nine other reports about the project that were analysed, most of which were compiled by other researchers.

Chapter 7 outlined the progression of information that was collected, analysed and refined into representative tables and figures. The key findings included establishing critical concerns for the students, including some that had not been heard in this level of detail before. One aspect of this newer level of understanding was that the concerns could be usefully described, by using social regularities that mirrored the key sense of community constructs, in a way that explained some of the key relationships between them.

From this more dynamic base of understanding students' concerns, sense of community became progressively depicted as a relational journey towards commitment or alienation. Because of the longitudinal nature of the research project, this mapping became more detailed, and a general framework was developed to present the dynamic tension within these types of journey. Thus commitment was understood as progressive, compromised or ceased. Alienation was understood as progressive, averted, enacted or enforced.

An ecological framework was also developed, and then applied in a number of case study situations. It illustrated the strength of PSoC concepts for intervention theory and practise. This framework incorporated the ecological contexts within which people experienced PSoC, as well as the dialectical tension that seems inherent in any full description of constructs of community.

A review of the pertinent literature with reference to the three objectives and four hypotheses of the research revealed that this project was one of the few that has attempted to present students' life worlds in such a comprehensive way. Similarly, whilst there was a growing research literature on community based educational practice, there was not a concomitant rise in understanding of the value of using community psychology's constructs on sense of community. The reviews revealed that given more resources and fore knowledge, the information obtained might have been improved to give more useful information (see 'recommendations' below).

It was noted in this discussion that community psychologists should be careful in what empirically can be justified for measurement as an attribute. It was suggested that psychological sense of community per se is a relational process that needs to be understood in terms of tacit knowing, and that its effects are that which could be measured by more quantitative methods.

The final review section noted that the tendency towards individualism could occur even when studying the relationship between communities. A suggested framework for consideration in future research was constructed to assist community psychologists to remember the multi-level nature of persons in relationship, in relationship.

Recommendations

1. That psychological sense of community still is used as one of, if not the primary, organizing concept for community psychology.

2. That the issue of the developmental mismatch for students moving through the primary/secondary divide be still considered as an issue of substance, particularly with reference to the compulsory nature of schooling.

3. That community psychologists be involved in school systems to help school personnel evaluate their teaching and learning processes as a relational enterprise – and in the particular case of emerging adolescents, to use psychological sense of community constructs to help evaluate the developmental sensitivity of the school structures. Having teachers that know students well, and vice versa, should be the underlying aim of such endeavours.

4. That the ecological and community constructs of sense of community be used systematically in planning interventions and that these constructs include social regularities within activity settings. These intervention plans should keep the metaphor of journeying within a commitment or alienation narrative as a critical outcome focus. A regular part of such narratives would be the recognition of the tension between the relationship forces within the community (the dialectic of relational compromise towards establishing a common vision for life together).

5. That the frameworks developed in this research be further tested in environments where the effects of increasing psychological sense of community can be more quantitatively measured.

6. That such detailed research projects be shared by a team of researchers, particularly for the cross validation of qualitative transcripts.

7. That networks and support structures for resident researchers be established for those adopting long term field placements. And

8. That community psychologists stay mindful of the broader conceptual contexts that are only now finding expression within the field – notably, the multiple levels in which communities in relation find themselves, and the apparently mutually important needs for sense of community and spirituality.

Final Thoughts

This has been a long journey, and the acknowledgements at the start of this report do not do justice to those who have been part of the community that has supported it. It is hoped that for these people who have been in relationship not just with the research, but also with me, the conceptual foundation of using an explicitly articulated and comprehensive framework of psychological sense of

community has offered hope to any community trying to develop a responsive environment in a compulsory setting.

It is suggested that without such a foundation, then this researcher would have been more prone to committing 'scientific heresy', if heresy is considered as taking part of the truth and exaggerating its pre-eminence in the scheme of things. Possible examples of this that are extant in the research and theoretical literature are the promotion of empowerment without communion; of advocating social justice without social compassion; of entering into social action without commitment; or encouraging prevention programs without reflection and renewal.

Thus, the opposite of alienation for this author has become more than the simple adding of the parts of sense of community. It is more than regularly coming together, although membership is important. It is more than being safe, although boundaries are important. It is more than experiencing compassion, although caring for and being cared for is important. It is more than routine connectedness, although regular mutuality in life's details is important. The opposite of alienation that has been conceptualised and developed in this research is a growth in commitment, which is the fruit of genuine renewal as a person in relationship.

Seymour Sarason, as a long time community psychologist with an almost equally long-term interest in education, has been oft quoted in this research and report. He again had a sobering reflection in a more recent article on spirituality and community psychology:

> Schools do a very poor job of helping students understand why learning to live with each other is both an individual and group obligation and why over the millennia our track record is not heart-warming (2001, p. 604)

Those of us community psychologists who are committed to work in education in schools can consider more carefully if psychological sense of community is a process, a relational journey to somewhere, from somewhere, whereby meaning is added to our experience by reconciling the compromising forces within our lives. Then we may have opportunity to offer some courage to some communities to achieve some degree of hope, instead of growing despair.

For in the framework of this study, alienation is the pathway to separation and its attendant relationship difficulties. Wholehearted commitment is the

pathway to deeper intimacy. Thus, our role as community psychologists is to be agents of invited intimacy. Without such a vision we are, as the old quote says, in danger of perishing.

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Appendix 1:

Interview Questions

1. Vision – *the Principle of Membership (belonging)* - does the discourse of the students indicate that they belong? What style of conversation is there? Questioning? Compliant? Contradictory? Persuasive? Is there personal acceptance and belonging tones? Does the language change across the year groups? [This last question can be asked for all 4 areas]

2. Ethos – *the Principle of Givens (boundaries)* - do the students in the community know the boundaries in which they live at school? What does the discourse say about what meaning is attached to these limits? What language choices are made with reference to School being 'their place'? What makes a 'good' teacher/class? What makes a 'boring' one? Is MS a safe place? Do they like the structure of MS, with regard to the experimental balance between the homeroom and specialist teachers?

3. Pathos – *the Principle of Compassion (needs)* - does the discourse of the students indicate that they believe that they are listened to? Does the construction of the discourse give any indication of patterns of what types of people they think are able listeners and who are not? What relational functions are achieved and represented during interview?

4. Connectedness – *the Principle of Connectedness (commitment)* - do the students want to be there? How does the discourse reveal that they express this as they go through their years between 5 to 8, and then into Senior School? What persuasions about school are presented? Resentment or hope? Keen or reluctant? Optimistic or pessimistic about the future at school?

Appendix 2:

Survey Questions for Students

The first page asked the following:

1. What do you think works well in Middle School?

2. What do you think doesn't work well in Middle School?

3. Do you have any general comments to make about life at school?

Page 2 aimed to produce more personally reflective data that was comparable to the focus group critical questions:

1. Is what is expected of you fair in Middle School?

Examples could include conduct in class; playground routines; homework; uniform; etc.

2. Are you listened to enough?

E.g. can you have your say about what is not right or safe?

3. Do you like coming to Pax Christian School?

E.g. would you like to be at another school?

After showing the first draft to homeroom teachers however, the page two questions were modified to as below:

4. a. What are the expectations of you that are fair or unfair in Middle School?

E.g. your conduct in class; playground routines; homework; uniform; etc.

4. b. In what ways are you more fair or unfair to your friends this year compared to last year?

5. a. In what ways are you listened to enough? When are you not listened to enough?

E.g. can you have your say about what is not right? Can you find someone to talk to if you believe you are not safe?

5. b. In what ways have you been a better listener this year, if you have?

6. a. If you like coming to Pax Christian School, why?

E.g. would you like to be at another school?

6. b. In what ways do you think that you are learning more this year? In what areas do you think you haven't learnt much?

Note that Chapter 4 describes how these questions were modified for the parents at the different stages of the five year research project.

Appendix 3:

Explanatory Communication with Parents for Student Interviews

Explanatory Letter:

This letter explains the interview procedures to the students and their parents.

PAX CHRISTIAN SCHOOL

Dear Student Leader's and Parents (current and past),

Last year (1997) I conducted a series of interviews with student leaders about Middle School. I will be doing the same this year, again recording the interviews for transcription and analysis. The interviews will be conducted in my office, with lunch being provided.

The basis for the interviews for years 6 to 8 this year will be reviewing the transcripts from last year's interviews. Year 5 will be asked about their start into Middle School from Junior School.

Please be free to ring me if you have any questions about this program. The results are used (anonymously) as part of the strategic planning of the school. I do the analysis as part of my graduate studies (the schedule of which is framed to help the school's enhancement program). Both processes help us fulfill our commitment to understand our emerging adolescents better, and thus to create better teaching and learning environments.

Could you please fill out the response slip below and return it to me at school so that I know that you have been informed about this program?

I look forward to getting to know the Student Leader's better over this time. Thank you for your support.

Yours sincerely,