Is anyone listening?

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Abstract

Emerging industries such as the life sciences, animal health, agricultural biotechnology and environmental products offer both a potential for economic growth and improvements in quality of life, crop and stock yield, the environment, and industrial productivity. The growth and success of these industries depends on a combination of good science and good business. Biotechnology, for instance, is one emerging industry that has promised much, yet the delivery still seems to be some way off. Difficulties convincing well-informed investors of the virtues of biotechnology may be indicative of a wider communication failure. Despite numerous initiatives to popularize and *sell* science, it seems the attitudes and understanding of society towards science and scientists and the importance scientists place on communicating with society remains depressingly low. One-way late-stage communication models have proven ineffective and have only further alienated the very audiences they meant to attract. Solving these problems requires the involvement of both the scientific community and wider society, where appropriate information is presented in a non-guarded and accessible language, and is received by open and willing ears, setting the scene for interactive, educated debates that can progress rather than hinder the science. This paper explores the various science–society interactions and identifies a need for early-stage two-way communication models.
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INTRODUCTION

The erratic performance of the biotechnology industry has been linked to society's shifting and often lagging scientific awareness, understanding and appreciation.[1] Today, despite over 20 years of public and private initiatives attempting to popularise and *sell* science, the difficulties bio-entrepreneurs face in convincing well-informed investors of biotechnology's virtues suggest that society may still be at cross roads with the scientific industry.[2,3] The attitudes, understanding and recognition of society towards science and scientists remains depressingly low and neither party has shown a willingness to commit to a solution. One-way late-stage (in the technology's developmental path)

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communication solutions have proven ineffective and only serve to alienate the very audience it means to attract. New two-way approaches, driven by public and private interest groups must be developed that bring scientists and society together at a time when both parties feel that their contribution is valued.

The traditional turn-a-blind-eye approach has allowed scientific *ignorance* (ignorance as defined in Stocking and Holstein, 1993)[4] to persist throughout the lay community and has hindered not only informed decision making but also the perception of science and its value. The erosion of these values has impacted, albeit indirectly, on funding for future scientific endeavours by inducing a reverse compounded Matthew effect.[5] With society's limited knowledge and appreciation of scientific matters coupled with a limited desire for scientific learning, the communication channels have further deteriorated.[2,6–8] While it is clear that the public is suffering from a deficit of science knowledge[6] and scientists are suffering from a deficit of societal empathy, the reasons behind this and the associated broader economic impacts are still being grappled with. This paper explores science–society interactions and identifies a need for early-stage two-way communication to be developed that helps reduce the distrust and anxiety the community feels towards science and the denunciation scientists feel from society.

UNDERSTANDING THE COMMUNICATION PROBLEM

The importance of disseminating scientific knowledge throughout the community has long been known and dates back to the age of Enlightenment in Europe.[9] Through the works of John Locke, Voltaire and Jean-Jacques Rousseau, the age of Enlightenment sought to instil through the community and its leaders an emphasis on rationality. Enlightened monarchs distinguished themselves from traditional monarchs by applying rationality to their territories and allowing religious tolerance, the press, freedom of speech and the right to hold private property, and many fostered the arts, science and education. Despite this history and today's increasing research funding pressures and commercial incentives, it seems that many established scientists (50+ years old) have become less interested in using their time for popularising and *selling* science. With research funding opportunities dependent on research output, these scientists view themselves first and foremost as teachers and researchers with commitments to their academic disciplines or professional fields.[10] Public engagement is viewed as a superfluous duty, feared to attract criticism from one's peers and even jeopardise academic careers.[11] While the lack of *selling* science training and the performance rewards/recognition system for public engagement that was encouraged during their professional developmental years has been blamed for many of these problems[12] understanding the core issue, why some scientists feel that the public undeservedly ignores their work and contributions is difficult. Fortunately, in fields like biotechnology and nanotechnology many of these attitudes have changed with academics in the younger generations, as these fields are perceived to be at the cutting edge of community–science interactions. Scientists in these fields are aware that they cannot work in isolation from the public debate as much as scientists in many of the other fields.

Scientific research is labour intensive and seeks to advance our knowledge and health. Scientists spend what time remains applying for limited and often fickle funding to secure an opportunity to research and a salary. While many scientists claim that the shortage of available research funds stems from the community's ignorance of the costs and time taken for scientific research, others (scientists and non-scientists) argue that this may be a consequence of the industry's inability to adequately articulate these costs and their importance to their research. But while society may not understand science, its processes or costs (as scientists do not well understand society), it appears that the financial hardships endured by scientists are understood. A recent survey reported that although ~80 per cent of society have a high respect for scientists, ~50 per cent do not want to see their children enter the profession because of the poor salaries and lifestyle.[13]

THE IMPACT OF INEFFECTIVE COMMUNICATION

These *poor* perceptions of the scientific community have manifested in decreases in the number of R&D personnel where in 1996–2002 Australia saw only a 3 per cent growth of R&D personnel.[14] According to the Commission on Professionals in Science and Technology in the USA, between 1998 and 2002 the number of science and engineering doctoral degrees awarded to US citizens at US institutions fell 11.9 per cent to 14,313 while doctoral degrees conferred in most other fields remained roughly the same over this period.[15] A report published by the US National Research Council identified comparative cumulative earnings disparities as the major disincentive for students considering higher science and engineering degrees.[16] By way of example, the National Association of Colleges and Employers indicated that in 1999 the average starting salary offer for individuals with a bachelor's, master's and doctoral degrees in computer science was 44,469, 55,438, and 58,688 US$, respectively. Assuming that tuition and fees for a one-year's master's programme total 20,000 US$ and that annual salary growth for both bachelor's and master's degree holders is 5 per cent, they reported that the total earnings for holders of these degrees equalises in ~10 years. More startling was that a fully supported five-year doctoral degree (effectively tuition and fees totalling zero) sees the total earnings equalise in ~50 years. While it is recognised that academics may have more freedom in their work than many other professions (eg medicine and law), escalating living costs are forcing many students to consider exit and future salaries when choosing career paths. Table 1 highlights various career earnings and employment rate disparities. The National Association of Colleges and Employers estimated that a true market wage for a PhD student would be between 40,000 and 60,000 US$ per year (cf 15,000 and 20,000 US$), while newly minted doctorates should be earning as much as 100,000 US$.[15]

WHY FIX IT?

Public funds remain fundamental to the establishment of cash hungry science and technology-based industries. However, as public investment in high-technology industries such as biotechnology is difficult and abstract, investment is typically indirect through managed funds (including tax-funded government granting schemes). Direct public investment in the industry typically begins following a company's listing on a stock exchange where investment preference is shown to the trustworthy and openly discussing company that listens to the demands and queries of its shareholders and customers.[17,18]

Funding opportunities for academic and commercial sciences are regulated by the

Table 1: Bachelor degree graduates, employment, further study and starting salaries, 2004 (%)

	In full-time employment (%)	Seeking full-time employment, not working (%)	Seeking full-time employment, working part-time or casual (%)	Further full-time study (%)	Median starting salary (USD,000)
Urban planning	92.3	4.5	3.2	14.6	40.0
Economics	85.1	6.1	8.8	25.0	38.7
Chemical engineering	84.2	10.8	5.0	28.0	44.5
Mining engineering	96.6	3.4	0.0	10.1	57.0
Dentistry	97.0	1.5	1.5	2.7	60.0
Medicine	98.3	0.3	1.5	11.4	45.3
Law	87.4	5.8	6.8	21.6	40.0
Computer science	70.5	14.9	14.6	22.6	38.0
Life sciences	69.0	10.8	20.2	47.3	36.0
Mathematics	64.4	18.2	17.3	45.3	40.0
Chemistry	78.7	10.1	20.9	54.7	38.0
Physics	69.0	10.1	20.9	54.7	38.0
Geology	79.3	12.9	7.9	43.7	40.0

Source[14]

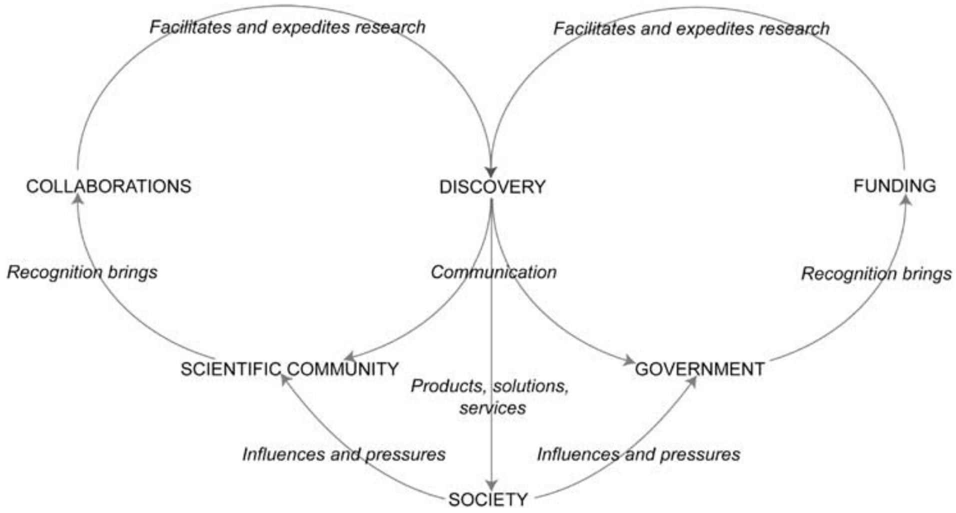

Figure 1: Progression and dependence flowchart of scientific development. Following a discovery, the scientist seeks recognition by communicating the findings to both the scientific community and government funding bodies. The recognition brings money and collaborations that help to facilitate and expedite research that can lead to new discoveries. If the discovery, the implications for society and other socially relevant information are communicated to the community, the additional pressure of public emotion influences government funding bodies and the scientific community. This encourages increased interest, collaborations and investment and helps future research endeavours and the acceptance of the product in the market. If the discovery is communicated poorly or not at all, society can negatively pressure the government and the scientific community thereby hindering future research opportunities

social climate regulating the governments spending and so investor ignorance can lead to significant reductions in funding opportunities. With the number and value of scientific breakthroughs entering commercial markets increasing, it is in the interest of all value-chain participants to aid the acceptance of these products in the market by educating the consumers on the importance, relevance and social good of science and scientific issues. As shown in Figure 1, society can exert an influence on scientific research success by influencing the opportunities for collaborations and funding showing why efforts to heal the science–society communication barrier need not stem from mere altruism.

The perception of a community-concerned scientist is even more relevant for the commercially driven scientist whose marketable-product hopes lie in the hands of the end-user's whims; society. Scientists must spend more time and effort engaging the public's interest and responding to changes in the concerns, emotions and interests of society, and come across as valuing these.

Table 2: Growth in global biotechnology, 2004–2005

	2004	2005	% change
Public company data			
Revenues (USD billion)	53.37	63.16	18
R&D expense (USD billion)	19.54	20.42	4
Net Loss (USD billion)	6.27	4.39	−30
Number of companies			
Public companies	645	671	4
Private companies	3,522	3,532	0.3
All companies	4,167	4,203	1

Source[20]

To help society feel involved and a valued contributor in the development, production and regulation of the technology, it is important that these happen during the early stages of the research, not after it is completed. The 2003–2004 growth of the Australian Stock exchange biotech sector (~18 per cent), the growth in global biotechnology in 2004–2005 (Table 2), and the growth of the NASDAQ biotechnology index over the 2005–2006 period suggest that institutional and non-institutional investors are beginning to grasp the mechanics of these industries and feel comfortable interacting and investing in fields such as biotechnology.[19]

HOW TO FIX IT

Relearning effective communication

Descriptions of the scientific world often involve technical jargon and *eschew anthropomorphisms*:[21] take, for example, the details that were first described to would-be consumers of genetically modified goods and the ensuing reception received.[22,23] Yet, while scientists can often blame a public's misapprehension or misplaced concern on a poor understanding of mathematics, biology and probability,[24] the public's risk assessments draw on a much broader range of data, typically including who will benefit, what the alternatives are, who is providing information that is being used in the decision-making, who is responsible, what could go wrong, what else could go wrong and the impact on the culture or society in general, even leaving out religion and morality from the analysis.[25,26] It can be the absence of this information that can make these scientific assessments unacceptable to the public and draw skepticism and criticism.[24] Adding to this problem is the poorly understood and thus suspicion-raising counterintuitive design of the scientific approach (ie it requires experimental design to gather evidence to test a hypothesis).[27] For the scientist, this has produced inherent caution with a guarded language, which has only added to the communication deficit and further hindered communication networks.[17,21]

In addition to appreciating differences in audiences, successful communication with society must help nurture trust, realistically address issues of concern and potential risk, be non-technical and must acknowledge the limitations of science.[21] With the specialisation and correlating fragmentation of science to a point where scientists are themselves unable to communicate with one another, it is essential that *trust* relationships be instilled through all levels of science and society. It is important to remember that we cannot know let alone be interested in everything, and therefore communication and information must reflect this. We have recognised since the work of Adam Smith that society is built on a division of responsibility and skills, a specialisation of labour – so in specialty areas such as science, where knowledge is lacking trust must be high. Along with negative emotions, trust can significantly influence both perceptions of risks *v* benefits of new technologies and public acceptance of new technologies.[28–33] In fact, it has been argued that trust in the management of technology-related risks can be more important than beliefs in the technology itself.[34,35] These researchers suggest that trust in business leaders or government is an important factor as it helps people reduce their subjective uncertainty and makes information processing more efficient.[36] More importantly are the negative perceptions private sector science receives courtesy of movies and views of profiteering and vested interests.[37–40] This knowledge/trust relationship will be crucial to resolving the science–society relationship.

Communication is best achieved when the parties are both interested in the topic, believe that the other is not manipulating the facts for personal gain, and when participating parties respect and respond to the knowledge, concerns and context of the other. Unfortunately, scientists and non-scientists can have very different views of each other, their interests and roles in society. As previously noted and illustrated in Figure 2, this problem is, in part, due to the degree of trust the public has in scientists[41] and the public's perception of scientists with vested interests. Just as scientists need to note disparity of public opinion and knowledge about science and appreciate that different subsets of the population require different forums for effective communication, the public must also acknowledge this in the scientific community.[21] Misconceptions such as *a science training* allowing one to be an authority on all matters *scientific* need to be corrected by more specific descriptions of professionals in the various scientific disciplines. The public needs to recognise that scientists are consumers too and are as concerned about the future of

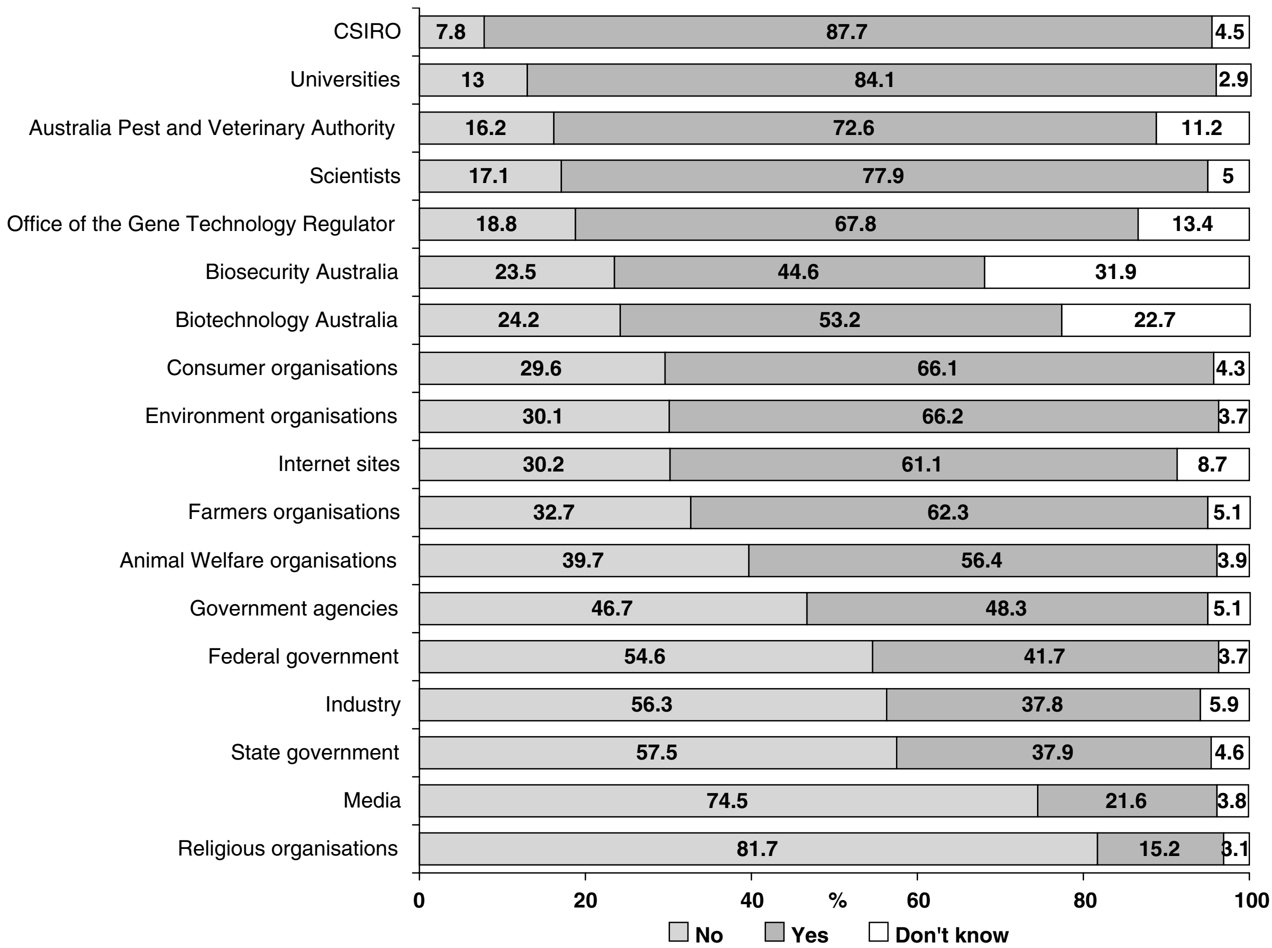

Figure 2: Australian citizens' confidence in provision of information by Australian organisations. Most confident: Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO), universities. Least confident: Religious organisations, media. Most unsure: Biosecurity Australia, Biotechnology Australia[37]

their children and the environment as non-scientists. The very fact that scientists may be perceived as disregarding the environment and social health in the name of scientific advancement is indicative of the severity of the problem; it is scientists who are working to improve the environment and social health.

The power of the press

Press releases announcing achievements in biotechnology act as amplifiers creating a ripple effect of increased public awareness of biotechnology issues and reducing problems associated with controversy focused reporting.[42] The dollar impact of successful media coverage is clear when reviewing the valuations of biotechnology companies in late 1999 and early 2000. Fuelled by optimistic media coverage of the sequencing of the human genome, investors rushed to the sector. The collective valuation of the 25 largest companies ballooned from US$117bn on 27th October, 1999 to US$245bn on 21st January, 2000, more than doubling in fewer than three months. But only three of these 25 companies were in the genomics sectors, and although all biotech companies were expected to benefit at some point from the exciting scientific advances of the moment, there was little basis for justifying an extra US$128bn in market capitalisation. There certainly had been an increase in information about the sequencing of the human genome, but information relevant to the value of biotechnology companies – R&D, pipelines, revenues, profits, business and strategic plans had not changed in any fundamental way during these three months.

To increase interest in a story, journalists will often pit scientist against scientist when addressing contentious public issues. The resulting accounts of science give equal, but unequally deserving weight to *duelling experts*, thus making the science appear more controversial and more uncertain than the bulk of scientists believe it to be.[43] Films, literature and other media styles have made further unhelpful contributions to the public's misinformed perception of scientists. These perceptions have done little to promote scientists as trustworthy and socially aware citizens.[21]

As an example of the media's predisposition for promoting controversy, in 1996 biotechnology as a subject was only covered in one out of every 12 daily editions of the *New York Times*. In 1997 with the controversial cloning of the sheep named Dolly, coverage increased in an episodic manner when press releases were issued about various biotechnology *incidents*.[44] By the end of 1997, in the annual Associated Press poll of newspaper editors, Dolly was ranked as the fifth most important story of 1997.[45] The media's attraction to controversy is unlikely to abate and so the scientific community must adopt strategies to minimise *bad press*. Being able to promote scientific research despite the media's penchant for controversy is becoming even more important as public media outfits continue to grow their influence on the minds and attitudes of society.

A review of science-related media reports and company press releases in major Australian newspapers during 1997–2005 pointed to a correlation between media releases describing inadequate government funding/support of sciences and increases in government funding/support for science-related research. In general, and as testament to the influence of the media, less than one month was required for the government to respond to negative media coverage. However, as shown by subsequent reports, the responses were typically less than what the scientists required. By way of example, in April 2006, the Australian Federal Government shocked the Australian marine research community when it announced it would not complete the proposed funding of the Marine Science Research Centres that would surround the Australian coastline saying that sufficient funding had already been given. Experts said that the benefits of having Cooperative Marine Research Centres would have helped to protect Australia's marine wildlife. This and other examples highlight the division between what scientists believe and what the community does, and points to a need for scientist–government–society communication improvements when describing what is required for scientific research. In addition, of the articles reviewed, only a handful gave scientific costs in real and laymen terms and very few papers recognised patents and entrepreneurial commercial science as equal to academic research-based science, which may explain why commercial science is perceived as less trustworthy than academic science.

Communication and media savvy scientists who can circumvent the media's affection for controversy can develop strategies aimed at mitigating some of the community's uncertainty towards science. Uncertainty does not necessarily impede science, but can propel it forward when placed in the proper and objective context of the scientific process.[46] These strategies may simply include appropriate scientific context in the public media coverage thereby increasing confidence and hopefully investment in the sector.[47] When communicating science to the public, denying the uncertainty (or the controversies that inevitably arise from it) is generally counterproductive as this information can add trust to the topic and scientist.

Designing solutions

Successful policies/responses will first have to aim at understanding what the community believes. In a large and lay system of public communication where the content of messages is necessarily limited by the sound bite or the headline, the public is continually left to make subjective judgments due to a severe deficiency of factual knowledge. From this subjective reality the public, usually led by the media, makes moral judgements usually in the forms of expressions of emotion, from outrage to enthusiasm.

These expressions of emotion, deemed irrational by some scientists and often dismissed as sensationalism or hysteria, may contain a great deal of data for those willing to make the interpretation: they indicate what is and is not acceptable in society at any point in time.[24,48] This is useful information that is often wasted, despite its descriptions of the moral climate of the society in which science and technology must fit to thrive. It is a dangerous practice for academics and bureaucrats to assume that the public is deficient while science is sufficient (the deficit model).[49–51]

Rather, there needs to be an appreciation of the public's concerns as well as their influence and accordingly look to strategies that can access and deliver the clear, non-value laden information to those willing to listen. These strategies will need to be tailored to the capacity of the relevant communication channel, which is proportional to its bandwidth and the power of the transmission, that is, the success of science communication will be dependent on the medium, content, style of delivery and relevance to those it is to be received by. It will be important for academics and bureaucrats to identify critical barriers to the effective and efficient flow of this information, and thus strategies may have to initially take the form of probabilistic communication models.[52]

The drive to educate society on matters scientific and to develop policies aimed at improving the science–society relationship is founded on the belief that knowledge informs attitudes.[36,53] This belief advocates that as science is learnt, the associated gains in knowledge will lead to more critical thinking and to a more positive outlook on scientific issues.[18] In the United Kingdom, a programme *Famelab*[54] has been designed to bring scientists and society together. The aim of the project is to encourage scientists to inspire and excite public imagination with a vision of science in the 21st century. The design of three-minute presentations with no slides followed by immediate and hard-hitting feedback from a panel of judges is intended to cut through the scientific jargon and bring the enthusiasm of the scientist, the key emotion that the public responds to, to the forefront.[55,56] The small monetary prize and the opportunity for a speaking tour attracts charismatic scientists, and in the audience, the inherently scientifically interested citizen. Programmes in Australia such as *New Inventors* are similarly designed.

Unfortunately, as shown by the limited success of past *selling science* initiatives, it is often those with ears and minds already open (such as the audiences of *Famelab* and *New Inventors*) that receive the message. This converted segment of the population is not the problem and should not be the target, but rather the vast majority of the disinterested, the waverers and the antagonists. The target audience should be those who are not interested in science, as it is with these that serious long-term social, fiscal and health improvements can be made. Programmes such as *Famelab* and *New Inventors* need to access this disinterested segment of the community.

WHO SHOULD FIX IT?

Determining the onus for change is almost as difficult as understanding the cause of the problem as typically both society and scientists are ignorant of the issue. Given that governments are only recently appreciating the economical advantages of having an internationally competitive scientific industry and a society that is scientifically aware, it is no wonder that communication has remained ineffective.[57]

With yesterday's star industries fading (eg oil and mining), economic prospects such as financial gains and employment benefits are beginning to focus the eyes and pocket books of governments onto the scientific industry that is in turn delivering a multitude of new and potentially life-enhancing discoveries. Through the application of these discoveries, the scientific community has enhanced the quality, comfort and longevity of the lives of individuals throughout the world, with assured future prospects of enhancing and sustaining life.[21,40] Nonetheless, many of the discoveries made by the scientists still have to be so dramatic as to capture public attention and thereby influence politicians who are the purse-string holders. Many scientists as a result still feel that society does not appreciate their contributions and as

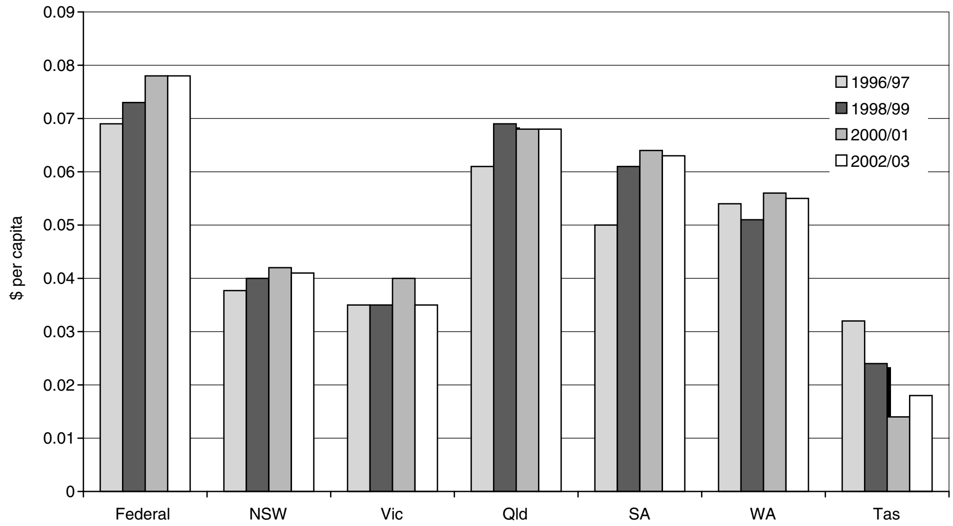

Figure 3: Australian government expenditure on R&D per capita
Source: [60]

possibly both a cause and an effect they continue to find it difficult to be the researcher and generator of discoveries while also being the communicator and mouthpiece of their own efforts. The advantages of communicating to the community seems to be filtering through to the younger generation of technology researchers who are now producing a comparable percentage of popular science papers to researchers in the humanities and social sciences fields, and almost twice as many as technology researchers aged over 60.[10]

Yet, our science and technology dilemma is becoming increasingly evident as reflected by Australia's drop in the 2004–2005 world competitiveness scoreboard from fourth to ninth. [58] Australia is now behind Iceland, Finland, Denmark, Hong Kong and Switzerland who, unlike Australia, have all shown increases in government science spending (Figure 3).[59] Reconciling the communication failures between scientists and society will require long-term government's-driven strategies and funding aimed at bringing together science and society in a mutually beneficial environment.

The limited understanding by the wider society on matters scientific has impeded government resolve and policies promoting science and increasing technology R&D expenditure. This has meant that government expenditure on science and innovation in Australia has risen by only 0.25–2.76 per cent of total GDP from 1981 to 2006.[14] Together with the alarming 8 per cent per student decrease in expenditure on tertiary educational institutions from 1995 to 2002 by the Australian Federal Government, the scene has been set for a long-term reduction in the pool of qualified scientists needed for continuing the growth and improving the social perception of the science sector. With participation of Australia's public in biotechnology policy undermined by the very institutional structures that were ostensibly designed to facilitate consultation, take for example the limited interactions *Invest Australia*, the *Australian Institute for Commercialisation*, and the *Department of Education, Science and Training* have with society, the government must make moves to treat the community as technological citizens who with appropriate information can make genuine contributions to policy making rather than just consumers of advice.[61] Australians have often been held up as some of the fastest adopters of new technology in the world. Why then should the Australian Government make the assumption that these same citizens will not understand the outcomes of scientific problem solving research?

Hollywood films can drive the public's attitude as movie themes correlate with public concern or interest. A study recently showed how the majority of the films addressing human cloning made between 1973 and 2005 portrayed the science as evil, unnatural, uncontrolled and dangerous.[39] In this study, the 16 movies for which there were data on cost and return cost an average of US$67m to produce. It is no wonder that Hollywood is having such an impact on the shaping of the science–society communication landscape with such enviable budgets compared to most science communication budgets. Following the release of the Hollywood film *Godsend*, US bio-ethicist Arthur L. Caplan:

> Thanks Hollywood. Just as people were beginning to understand cloning, you have put greed before need and made a movie that risks keeping ordinary Americans afraid and patients paralyzed and immobile for many more years.[62]

The stereotype of the mad scientist, whether mad malevolent, mad keen or just plain mad perpetuated by the film industry persists possibly because filmmakers have as little contact with scientists as the majority of the public. US science journalist David Ewan Duncan has said,

> the never-ending stream of batty scientist flicks reveals an underlying anxiety and fear about the possible dark side of the technology.[63]

Accessing, appealing to and educating Hollywood and other popular media directors, producers and writers may prove instrumental in improving the impact of science on the community and promoting scientists as responsible and approachable members of society.

CONCLUSIONS AND SUGGESTIONS

A report[6] on science and society issued in 1985 called for the responsibility of acknowledgement to lie with the scientist and that to improve the success of scientific innovation it is necessary to increase the media's focus on science to prepare the *market* for the *product*. Unfortunately, the onus of finding and delivering a solution remains unresolved[24] and the typical government solution of giving token funds that seem sufficient to society are in reality insufficient in both dollars and time. Any solution for the science–society communication conundrum or for society's scientific knowledge lacuna must involve finding a means to attract the scientifically disinterested, to deliver relevant and timely scientific information to laypeople and in training scientists not just to communicate in a more accessible language, but as a precursor, to understand why this is important.

Amending financial disparities will go a long way for promoting science as an attractive career option. This will also help to gain society's acceptance of the scientific industry, as more scientists in society will by osmosis and familiarity improve the general acceptance, understanding, appreciation and respect of the industry in the eyes of the public. But while scientific literature is remaining static relative to agendas in popular literature (ie scientists are not addressing the scientific questions that society asks)[42] and government expenditure on R&D in the OECD dipped by around US$680bn from 2001 to 2003, there are early signs that scientists are beginning to communicate effectively as the perceptions and recognition of science seems to be gradually improving: for two years in a row, in 2005 and 2006, scientists have been presented with the prestigious and high-profile Australian of the Year award. But for due recognition, funding and rewards to be achieved, a much stronger emphasis on communication is needed through the scientific community.

Regardless of the medium for communication (shopping malls, local pubs, railway stations, television), the information needs to be delivered in a manner that is – and these will most likely be dependent variables – interesting, enjoyable and applicable to the audience. The often repeated statement 'now here's another pretty picture', the not-so-subtle, disdainful comment offered by many researchers during presentations of otherwise interesting and elegant results, does nothing to encourage scientists to communicate in ways that are not only accessible but that catch the public's attention.[64] The visual expression of research is a powerful means of communicating important science and engaging the typically disinterested. Educating scientists to include visually attractive results will aid the communication and understanding of science across the various fields of knowledge and experiences that make up society.[64] Negative experiences will detriment not only the retention of information received during the current transmission, but also those of future interactions.

Charismatic scientists, through processes described under the Pygmalion and Galatea effects,[65,66] will have more success in effectively communicating with society than non-charismatic leaders. Their ability to exude confidence, dominance, trustworthiness, a sense of purpose, and their ability to articulate their vision/discovery in a manner that society can understand will by the force of their own excitement and enthusiasm induce society to follow and accept the vision/discovery.[67] So while we have Pygmalion, Galatea and Matthew Effects all potentially working in the scientists' favour, if the lead scientist is not charismatic or a good communicator, and if their ego permits, communication duties may need to be deferred to a colleague or administrative/business assistant who can ensure that the message is transmitted correctly and enthusiastically. Books such as *A Field Guide for Science Writers: The Official Guide of the National Association of Science Writers* and institutions such as *Biotechnology Australia* may prove indispensable to the scientist wishing to improve the public's accessibility and understanding of their work.[68]

Finally, and as described in Figure 1, it is important for scientists to appreciate the cyclical nature of communication. Appealing to and engaging with the community helps to not only improve the living standards of society by improving informed decision making, but will also give the government, society's representative, a reason to fund.

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