SCIENCE R&D AND IMPLEMENTATION: PROBLEMS OF COMMERCIALISING SCIENTIFIC ACHIEVEMENT IN AUSTRALIA

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Simply defined, implementation is the process of putting into practice something new to those attempting change. More accurately, however, from both a theoretical and practical perspective it is better described as a cluster of co-dependent processes involving knowledge acquisition, management and support, trialling, feedback and mutual adaption. This paper considers the potential influence of scientists and technologists on implementation. It is argued that there is scope, even a responsibility, for scientists to participate more fully in the productive cycle beyond R&D.

Keywords: Implementation, innovation, feedback, mutual adaptation.

Twenty years ago in his *Structure of Scientific Revolutions,* Thomas Kuhn[1] argued that science was more than a collection of achievements, more than a constellation of theories and methods. Science was as much an expression of beliefs. Theories survive when supported by current beliefs, but slip away as beliefs change. Increasing numbers of scientists, for example, are seen in the media adopting a world view, a holistic view, a conservationist view. Scientists are extending their activities beyond the laboratory and the field to participate in the processes and politics of technological and attitudinal change, acknowledging perhaps that scientific achievements and derived technologies are sustained only to the extent that life is breathed into them. More particularly, it is recognised that implementing scientific and technological achievements can facilitate growth in a stuggling Australian economy.

The purpose of this paper is to supplement this diagnosis by (i) examining links between scientific research and the implementation of innovative technologies and (ii) proposing strategies likely to encourage their effective implementation. Jevons recently reminded us that "the link between research and its applications remains one of the less well understood features of the modern world"[2]. Further, he emphasised the importance of supporting "contexted technology" in local economies if we are to improve the effectiveness of implementation. His claim that there is more to science and technology than research and development is the assumption on which this paper is built.

Simply defined, implementation is the process of putting into practice something new to those attempting change. More accurately, however, from both a theoretical and practical perspective, it is better described as a cluster of co-dependent processes involving knowledge acquisiton, management and support, trialling, feedback and mutual adaptation. But what scope is there for scientists to participate more fully in these productive activities beyond R&D? How should the business of science and technology be extended to include implementation of new technologies, capturing significant achievements before they are fed for development to multinationals overseas?

To illustrate: Earlier this year Dr Alex Dickinson was trapped in sub-zero temperatures at Denver airport. An expatriate Australian and an engineer, he was returning to the United States having visited his home in Adelaide. A combination of long flights and airport stopovers had given him time to think about the economic problems of Australia and to arrive at one or two solutions — often the case when one travels abroad. His thoughts are offered here, and I quote:

> Manufacturing success begins with research, but funding research means taking financial risks. To take risks there must be evidence of high return on investment — evidence that does not exist in Australia. But most research in Australia is government funded through universities, CSIRO and the military. Companies therefore can avoid research commitments and if a company hasn't had to take the financial risk of paying for research it has little motivation to take the much greater risk of developing and manufacturing the results. Meanwhile, few ideas emanating from government funded research find their way to profitability in Australia[3].

The Prime Minister and the Leader of the Opposition make similar points in their *One Nation* and *Fightback* packages. For example, to paraphrase from *One Nation*.

> Too few of Australia's research successes are exploited commercially for the benefit of Australians. Both the Block and Couglan reports identified an underdeveloped equity market for small to medium sized firms. The government's decisions are designed to improve the access of such firms to equity capital and to promote the commercialisation of research findings[4].

Most of us would willingly acknowledge the persuasive strength of these claims, but how many would criticise their failure to recognise the importance of construcive implementation practices and the contribution of those practices to improved commercialisation of science and technology in Australia.

Five years ago, a Task Force on management of technology in the United States offered the same advice[5]. Since then it has become clear, both in the United States and in Australia, that investment in R&D and the purchase of advanced technologies are themselves not enough.

Incomplete understanding of a given technology and its potential, contributes to a widening of the competitive gap between Australian manufacturers and our overseas competitors[6]. In short, the problem is both technico/scientific and managerial; the former focussing on the attributes of the given technology and its adaptations; the latter on the strategies employed to manage the introduction and effective consolidation of the new technology.

If we accept various recent reports: The Block Committee[7], Pappas Carter[8] and the IR&D Board[9], scientific research falls far short of innovation. This is because (so it is argued) innovation is of no consequence until new ideas are successfully implemented, a task requiring an investment of substantially more time, effort and money than the creative input of the scientist. Arguments like this are beginning to stick, and given our current economic malaise, a case can be made for the creative skills of scientists and technicians to be employed not only in the course of R&D, but at later stages of the implementation sequence.

Historically, our R&D investment has been skewed towards agriculture and mining. And there can be no doubt that these industries in Australia are among the most efficient in the world. By contrast and until recently, R&D investment in the manufacturing sector has been minimal and perhaps unnecessary, given the level of tariff protection and the well entrenched dependence of many manufacturing industries on the R&D of other countries. Progressive removal of protective tariffs, and associated survival imperatives have stimulated industralists to look for greater productive efficiencies through R&D. Yet much still needs to be done to lift our manufacturing industries out of their third class status to a level at least at par with mining and agriculture. To quote from the recent IR&D *Annual Report:* "manufactures need to overcome a number of hurdles such as venture capital access, intellectual property protection and export marketing distribution channels"[10]. . .to compete internationally.

In its mission statement the IR&D Board aims:

- To increase the efficiency and international competitiveness of Australian industry by maximising the contribution from industry research and development (IR&D)
- To develop an over-all strategic view of industry research and development in Australia in such a way as to assist in:
  - the identification and removal of impediments to achieving the primary objective;
  - the allocation of scarce resources in a manner designed to complement industry strategy; and
  - the identificattion of opportunities for international collaboration.
- To manage the programmes it is responsible for in a competent manner and to provide a high level of customer service and satisfaction[11].

Both in its annual reports and its mission statement the IR&D Board is concerned that manufacturing industry becomes more competitive, more innovative, more efficient. But again no reference is made to the contribution of effective implementation to achieve these goals.

A recent report on technology strategies employed by Australian industry based on a survey of thirty-six Australian companies confirms five characteristics of Australian industry:

- By international standards Australian firms are not active adopters and innovators;
- they are inclined to adopt conservative practices of introducing only the most proven of technologies;
- smaller firms tend to be more aggressive as they seek to be first to market new products;
- there is a strong correlation between R&D investment and innovativeness; and
- the most important source of innovativeness is in-house development and engineering[12].

The evidence suggests that more serious consideration be given to planned and more venturesome implementation practices in industry.

DEFINING IMPLEMENTATION

Until the 1970s the term was rarely used in research literature and frequently confused with adoption[13]. In the sixties, for example, Rogers, Clark and Guba, and Havelock[14] perceived adoption as an end-point in a sequence of processes leading to planned change. By the mid seventies, however, the term implementation emerged from obscurity to become the focus of a growth industry. Majone and Wildavsky[15] envisaged implementation as a practical expression of policy — an interactive process in which putting innovations to practical use could well feed back to authors and decision makers. Concurrently, Fullan[16], working with educational technology, defined implementation as the process of putting into practice an idea, programme or set of activities new to the people attempting or expecting change.

In a sequence of studies conducted in the United States by the Rand Corporation in the seventies, Berman and McLaughlin[17] examined the complexities of implementation. Their conclusion was that implementation was more effective, not only when there was encouragement and freedom for the user to adapt to change, but when the innovation could be modified to meet local conditions. This bilateral process was dubbed mutual adaptation and was considered to be crucial to the consolidation of an innovation in most settings.

It is useful here to distinguish between the practices of marketing and implementation. The former, when successful, results in improved sales and an improved level of acceptance of technology in the marketplace. By contrast implementation is consequential to the acceptance of technology and is more concerned with its successful installation and its use to achieve maximum effectiveness. Questions associated with implementation include:

- What support is needed to achieve effective use (technical, organisational, staff developmental)?
- What adaptations of the technology are appropriate to meet local needs (i.e.,consideration of context and specific needs)?

- What use should be made of local change agents (individuals within the organisation and outside who can substantially influence the implementation process)?
- What evidence is there of implementation variability from site to site and user to user?

Two dependent variables lie behind these questions: (i) the degree/extent of technological implementation and (ii) the influence of the several processes that contribute to it. Thus, the essence of implementation inquiry is to determine (i) the effectiveness of implementation processes and (ii) the extent or degree of achievement. The first is formative, the second summative in orientation.

DEFECTIVE IMPLEMENTATION

Australia's track record of implementation thus far has been punctuated by deficiencies, lost opportunities and failure. Scientific discoveries and new technologies have been passed on too frequently, too willingly, to vigorous economies overseas. Recent experiences surrounding high tech solar batteries, gene-shear technology, the Sarich orbital engine and various medical technologies demonstrate how unwilling we are from time to time to put Aussie life into a new exciting technology, even after substantial commitments of time and expertise and the investment of considerable working capital.

Last year Dr Michael Tyler[18], Associate Professor of Zoology at the University of Adelaide, reported that extracts from the skin of tree frogs in the Kimberleys contain at least forty peptides with anti-bacterial/anti-viral properties. His efforts to gain support from industry to follow up this discovery failed. Finally, he was forced to negotiate a joint venture with an overseas company. His talent and his creative achievements were captured for development outside Australia and an implementation opportunity was lost. This case emphasises an important point: implementation cannot be taken for granted. New ideas need nurturing and practical support; their introduction to industry and the community at large must be carefully planned and monitored; their endorsement predicated more to long-term productivity than short-term rewards.

Quotable examples of ineffective implementation and lost opportunities abound. An electronic mail facility is installed within a business house in Perth but staff continue to write memos. Solar pumps installed in the outback of Western Australia to improve irrigation fail because servicing instructions are inadequate. Software purchased to deliver up-to-the minute budget information cannot be accessed by corporate decision makers. Marketing protocols prevent the introduction of new flexible lens technology developed by ophthalmologists in Perth. A scientific discovery of benefit to cancer victims fails to attract attention of manufacturers in Australia and is lost to overseas competition. Each of these examples argues against implementation being left entirely to the market place. Effective implementation is never unplanned, never lacking the energy and purpose of originators and the commitment of developers. It must be assumed that users and clients will be unaware of all the potential benefits of the innovation and those entrusted to its use may not have sufficient skills and technical know-how to realise its full potential. It follows that scientists and technologists should project their talent and enthusiasm variously into the marketplace; to the shop floor and workbench in industry and to the kitchen and lounge room in the home for implementation to be more than partial. New technologies require new skills and new technical know-how. Systemic problems should also be anticipated. Consider as examples, uncertainties as to who controls the innovation, problems associated with lack of support from middle management, failure to adapt the technology to the local environment and insufficient 'need-pull' over 'product push' from operating staff and users.

Concerns have been directed at the implementation of both user technology and production technology. In his research in Norway, for example, Holt[19] found that first-time users of new technologies were seldom considered by decision makers. Working separately in the United Kingdom, Barclay and Lunt[20] concluded that while economic and technical appraisals were routinely made of new technologies, implementation processes and procedures were not monitored and were largely ignored. In short,research suggests that during the process of technology transfer, implementation processes are likely to be overlooked or under valued for their contribution to change. During implementation the emphasis shifts away from scientific and technical considerations *per se* to interchanges involving the user and other persons at the marketplace. Yet, it is also a time when scientists, developers and those responsible for implementation should work co-operatively to ensure effective introduction of the innovation.

In Australia, however, as in other countries, new technologies have potential to destabilise relationships in the workplace. As new work practices and responsibilities emerge so too will uncertainities amongst individuals attempting to adjust to new demands. Secure life styles associated with well tried practices are threatened by innovations. It follows, that preparation for implementation is essential if maximum advantage is to be gained from the technology. Lack of preparation invites subversion of employment and may result in shelving expensive equipment or domesticating a technological advance to insignificance. Such a crisis-driven scenario could force management to use band-aid solutions to patch up problems generated by inadequate preparation. Here again, the advice of those who developed the innovation should be sought.

EFFECTING TECHNOLOGICAL CHANGE

Given the complexities of implementation, it should be carefully planned and managed. Following a decision to adopt, a sequence of implementation processes should be activated. Knowledge of the innovation and skills associated with its successful implementation must be communicated to the workforce. Human and material resources must be provided to ensure effective operation. Equally important, shop-floor leadership through to senior management must be seen to endorse the innovation by motivating staff and providing convincing reasons for a commitment to the new technology. Finally, studies confirm that implementation effectiveness improves when scientists and developers remain responsive to user reactions and assessments[21].

Put differently,incentives may be employed to complement all stages and aspects of implementation; re-direction of funds, provision of additional staff, creation of promotional opportunities and so on. Equally important is adequate two-way communication between the technologists and scientists responsible for the innovation and those actively implementing it, for insufficient planning and management of implementation and adherence to a linear model of change can stifle feedback and adaptation. This is particularly the case where innovative technology imported from overseas, is subject to stringent implementation requirements under distant surveillance by the parent company.

Effective implementation of production and user technologies is predicated to successful articulation of the aims and needs of (i) those responsible for its development and (ii) those who will benefit from its use in the workplace. Enthusiasm for technological change is not enough. Implementation is best achieved by careful planning, establishing a supportive infrastructure and fostering teamwork amongst participants; scientists, technicians, change agents and users. Recent research[22] targets ten issues for special attention (Figure 1) and Edosomwan[23] claims that from a management perspective, successful implementation demands adherence to six principles summarised as monitoring, co-ordinating, communicating, cost controlling, analysing and co-operating. He notes that promoting the implementation of a new technology can generate problems (Figure 2) most of which will be avoided by exercising the above principles effectively. Gaynor[24] proposes a series of twelve questions each of which anticpates a possible implementation problem and each serves to direct decision makers towards effective implementation. Edosomwan concludes that "implementation of a new technology in the workplace is perhaps one of the most interesting and challenging experiences for decision makers"[25]. He warns, however, that projects fail because of ineffective implementation — lack of teamwork amongst developers, decision makers and users and failure to prepare adequately for technological change.

In 1989, the writer conducted an implementation study[26] of a newly introduced colour laser copier on eight business and industrial sites in Perth. The copier was computer controlled, innovative technology offering a substantial advance in the market place, a sensitive machine

FIGURE 1
FACTORS LIKELY TO INFLUENCE IMPLEMENTATION

1. *Leadership* from head office and locally.
   Commitment to senior staff.
   Active support from decision makers.
   Planning by decision makers to achieve specific objectives.
2. *Knowledge* of and confidence in the new technology; trialling and use in an unthreatening environment.
   Input from scientists and technologists.
3. *Funding* to support implementation including adequate time for skill development and understanding of the potential of the technology.
4. *Motivation* to sustain the implementation effort. Includes encouragement from senior technologists and scientists responsible for the technology.
5. *Participation* of technical staff in the range of implementation activities:
   trialling the technology
   training to cover new skills
   planning implementation strategies
   monitoring progress towards implementation
   assessing the value of the technology
6. *Communication* amongst all participants, i.e., sharing problems and successes to ensure a motivated and co-operative technology team.
7. *Training,* especially during the introduction of technology, but also as routines are established and as further advantages of the technology become apparent.
8. *Demonstration by example* to illustrate the merit of successful implementation by fellow technicians and users.
9. *Accountability.* Monitoring of performance and accommodating to feedback from technicians and users.
10. *Rewards* for the workforce. Options include financial rewards, improved conditions of employment, and promotion.

FIGURE 2
PROBLEMS ASSOCIATED WITH THE IMPLEMENTATION OF NEW TECHNOLOGIES

1. Resistance to change from old machinery to a new type of equipment or from a manual method to a technology-assisted method. People resist change depending on how they are affected by the change.
2. Unwillingness to change work habits.
3. Fear of the unknown. People are often afraid that technology implementation might cause unemployment, decrease job satisfaction, and increase psychological stress.
4. Inappropriate vendor support for equipment specifications, documentation, and service.
5. Lack of proper project planning and monitoring by implementation team members.
6. Conflicting views of objectives and lack of clear definition of the use of technology.
7. Failure of specific equipment or implemented technology to deliver the expected result, so that additional process and procedural bottlenecks are created by the new technology.

incorporating many innovative features including colour conversion, image composition, paint mode, multi-page enlargement and direct copying from colour slides and colour negatives. Of special interest to cartographers and others using complex multi-colour diagrams and photographs, the copier had performed with distinction on trials. Indeed, colour laser technology was set to capture the copying market. Yet, the study identified at this late stage, a number of implementation inhibitors. In particular, the training and skills of the operators placed severe limitation on the use of the machine.

Of twenty innovative features, only four were used substantially in the eight sites investigated. Four innovations rated highly by the manufacturer were not used by any of the operators. Strong requests from two users for the development of an interface allowing direct input of colour graphics and desk-top publishing data from a stand-alone computer were not actioned despite successful trials of such an interface in Melbourne. Significantly, the sites which demonstrated the most versatile use of the machine, two of the eight, were managed by individuals who had received training in Sydney on colour laser technology. It was their knowledge of the technology, their understanding of its potential, that led to effective implementation. Colour laser copiers retail anywhere between $50,000 and $200,000. Given such a financial outlay, one would assume that every endeavour would be made to maximise implementation. In practice, the study demonstrated considerable under-use because technical know-how was not being communicated effectively. Technical support, though entirely adequate in terms of maintenance, did not impact adequately where it was needed most, to ensure that the machine was used to its potential for commercial gain. Findings are summarised in Figure 3.

FIGURE 3
IMPLEMENTATION OF THE COLOUR LASER COPIER: A SUMMARY OF RECOMMENDATIONS

1. Initial training is adequate but follow-up courses should be mounted for users and supervisors to explore the full potential of the copier.
2. Users should receive basic maintenance training to avoid "down-time".
3. Company technicians staff should be aware of the power they have over users of the copier and seek to maintain positive relationships with users.
4. Company technicians should call regularly to check components and generally to exercise preventive maintenance.
5. The company should provide an implementation schedule to assist users through early stages of implementation, e.g., nominating short-term goals.
6. New users should be introduced progressively to the more sophisticated/complex capabilities of the copier.
7. Users should be given staged support as they gain in proficiency.
8. Implementation support by the company should be clearly documented.
9. New users should be aware of the influence of locational and contextual differences on implementation of the copier.
10. The company should actively explore ways of interfacing the copier with desk-top publishing, mapping and outer computing capabilities.

CONCLUDING COMMENTS

This paper began with a reference to Kuhn who defined science as a collection of beliefs. Those beliefs are currently undergoing substantial change. The bomb brought scientists out of the laboratory; confronted scientists with social and political dilemmas. Now, competitive economies in recession are using economic tools to channel scientific effort to achieve 'clever' economies. If, however reluctantly, scientists accept this condition, they are bound to become increasingly involved in implementation. It follows that much more will be said and done in the future to strengthen implementation practices in Australia. There is also much more for industries to learn to achieve a commercial advantage from technological change:

1. Adoption of a technology never guarantees its implementaton. Effective implementation is perhaps best evidenced when complex production technology is transferred into a new site, the motivation being improved performance, better quality and increased output. In addition, however, implementation is an important consideration during R&D and during the development of an innovation.
2. A top-down forced approach to implementation will not always work since it takes time, planning, financial backing and co-operative effort. As Keen recently claimed, "the lead time for major business innovations that depend on a comprehensive information technology platform is close to seven years"[27]. Yet there is room to explore ways of fast tracking the effective introduction of complex technology.
3. Funding of R&D does not guarantee implementation. At current prices, in 1988-89 $2.29 billion[28] of Australian taxpayers money was channelled into R&D and increasingly the question is asked: What is our return on this investment? It is claimed here that greater returns will stem from disciplined, committed, planned and well executed implementation of innovations. Decision makers in Australia have suffered from what might best be described as delusions of adequacy. Fortunes were made and the economy thrived on our extractive industries. Sadly, as we emerge from recession our industrial profile remains much the same. Despite some signs of growth in the manufacturing sector of Australia, production of semi-processed raw minerals for export continues to dominate[29].
4. Collaboration will enhance implementation, particularly if scientists and technologists are closely associated with activities beyond R&D which is perhaps why in-house R&D is found by Alex Dickinson and others to be the most successful route to follow. Installation and attempted use of advanced technology without such collaboration invites the workforce to subvert and domesticate it. At best, poor collaboration will result in under performance, at worst, total rejection of the innovation. Collaboration between industry and universities could be a lot stronger. For example, in a recent study, Lawrence

identified 64 forms of collaboration in Australia. Of these, only nine could be nominated as occurring better than rarely[30].

5. It is time that staff training programmes targetted specific implementation problems. A 1991 survey of over 300 electronics companies in the United States showed substantial untargetted staff training. Predictably, 63 percent of the 300 companies investigated had failed to implement new technologies effectively[31]. Findings of this kind challenge the wisdom of the Federal Government allocating $30 million to establish a new Australian Technology Group to translate Australian ideas into industrial reality[32]. What implementation skills will be evidenced in the group? How will such a group oversee such a wide variety of innovations in widely varying contexts? Not unexpectedly, concerns have already been expressed that this initiative could generate wastages of time, effort and funding.

R&D is not the end of a sequence. Steering a new product into the market place demands management and marketing expertise. It also demands knowledge of the product and its potential. For this reason, it is argued here that scientists responsible for an innovation should maintain close links with its implementation. Indeed, effective implementation is more likely to be achieved by the co-operative involvement of researchers and developers with those responsible for the implementation of an innovation be it an intellectual product (software) or hardware. Continued involvement of R&D personnel has the additional benefit of accommodating feedback from users suggesting perhaps creative product modification and new unanticipated uses. Our current performance is inadequate. Too often, for example, implementation commences before goals have been specified and before adequate resources for training and user support have been confirmed. Again R&D specialists responsible for the innovation are well placed to recommend training procedures, advise as to appropriate training outcomes and to respond to feedback from users during implementation. Collaboration with R&D personnel is helpful not only to the implementers. It also provides necessary developmental feedback to assist with furthur R&D. In short, industry and R&D will benefit from a conjunction between innovation and implementation. Such shared commitment will maximise the effectiveness of innovations and minimise needless rejection of Australian scientific achievements.

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