



Technology and knowledge transfer— good practice guidelines

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Synopsis

For technology transfer to be successful a process, from research to full scale application, has to be followed. This paper describes such a process and how it is applied in practice. Some of the 'do's' and 'don'ts' are highlighted. Recommendations are made on how to communicate existing knowledge and to ensure that a framework exists to effectively plan future projects with final technology transfer objectives firmly in place. The Impact Ripper System is used as a case study to illustrate lessons learned.

Key words: Technology transfer, implementation

Introduction

Since the inception of mining-related research in South Africa over 100 years ago, much knowledge has been generated. However, despite attempts to communicate this knowledge, it is doubtful whether the best results have been achieved in the transfer process. With the challenge lying not in the investment made in developing new technologies, but in the process required to ensure their effective utilization, this paper aims at identifying the principles for effective technology transfer and then reviews a case study of the Impact Ripper System.

The literature survey¹ included an internet survey, a library search, and a review of work by CSIR: Mining Technology. The most serious problem encountered was the limited mining-specific material available. However, aspects of successful transfer are often sown in seemingly unrelated disciplines and insight from multiple disciplines is necessary for a better understanding of the complexities associated with technology transfer.

Theoretical background

In attempting to develop a central theory for the transfer of technology, several different definitions of this term were used in the literature. The definition decided upon as the point of departure for this paper is: 'Technology transfer is the managed process of

conveying a technology (be it a product, process or a body of knowledge) from one party to its adoption by another party, e.g. from a developer to a user, a seller to a buyer, one department to another'.

This definition implies that technology transfer is a planned process. Furthermore, the definition recognizes that:

- Technology transfer is a multi-stage process by which an invention or research results are transformed into a marketable product
- Conveying suggests a process of passing the control of a technology from one party to another
- Technology transfer involves participants, the one being a source (thinker, conceiver, developer, generator) and the other a receiver (user, adopter, implementer)
- The technology or object that is transferred is not limited and could be knowledge or know-how, physical equipment, safety systems, facilities, results, products, services, information or procedures to name but a few
- Adoption presupposes commitment (emotional and financial) to routine use.

In the past it was generally assumed that science would more or less naturally evolve into technology which would in turn be commercialized. As world-wide competitive and economic pressures have intensified, attempts were made to quicken the technology transfer process. The appropriability approach of the late 1940s implied that technology transfer was a passive approach based on the belief that quality R&D would automatically be adopted by the end user. The dissemination approach followed, with the emphasis on

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developing dissemination mechanisms to inform potential users of available research outputs.

The most recent development, and the approach adopted, is the knowledge utilization approach which emphasizes the interaction and mutual dependency of researcher and end user in the technology transfer process. The focus of this approach is on the structure of interpersonal communication. The approach sees two important barriers to overcome in successful transfer of technology. These are inadequate personal communication between producers and end users and inadequate attention to barriers within the organization receiving the new technology, termed the receiver organization.

A review of the technology transfer models strengthened conclusions derived from the technology transfer definition and further emphasized that:

- ▶ Technology transfer should not be viewed as a linear process. A linear process does not adequately account for feedback and implies an orderly process
- ▶ The technology transfer process should not only focus on an exchange of information, but also on increased understanding of the circumstances/context/functioning of the organization that is receiving the technology
- ▶ The transfer mechanism usually requires agents. It depends on the movement of people and not solely on the routing of information.

Key factors that influence technology transfer

There are several factors that influence the success of the technology transfer process. The literature often refers to these factors as 'barriers' or 'constraints'. This paper refers to them as influencing factors, as the other terms have negative connotations which may not be true of all the factors.

Successful technology transfer involves careful manipulation of this complex system of factors to take full advantage of potential synergy within the system. The factors include those that can be controlled such as technical competence, and those that are more difficult to control such as socio-political conditions. Examples of the latter are:

- ▶ Economic structure: global trade, job creation, supply and demand, state funding, trade agreements
- ▶ Social legacy: illiteracy, values, culture, previous exposure to new technology
- ▶ Political framework: political stability, protection of monopolies
- ▶ Industry standards and regulations: performance requirements, applications, bureaucracy, formalized procedures, institutional policies
- ▶ Legal aspects: intellectual property rights, transfer agreements, licensing, patent rights, royalties.

The paper will focus on those factors that can be controlled.

Organizational/institutional factors

The following factors that are related to the receiver organizations to which technology is transferred should be considered carefully:

- ▶ The pace of technological change is usually faster than the rate at which organizational changes can be assimilated and institutionalized. This poses a problem as employees have to be sensitized and prepared for change, and organizational systems and procedures have to be modified to deal with the changes
- ▶ A receiver organization's capacity or ability to absorb new technology is influenced by the level of prior, related knowledge and expertise (i.e. basic skills, shared language, technological acumen, functional specialists) in the receiver organization
- ▶ A culture of action orientation, risk taking, receptiveness to internal and external breakthroughs, and a high tolerance for failure should be present.

In the mining industry this issue is complicated by the often short tenure of senior management on the mines who may be unwilling to support long-term technology development when they will not be in the position to enjoy the benefits. The case study on impact ripping clearly highlights the importance of educating the workforce on the need for the new technology as well as the importance of follow-up actions by management.

Human factors

People are the key to successful technology transfer, as people and not papers transfer technology. This implies that the people in the transfer process have to be:

- ▶ informed about the process
- ▶ consulted about their needs, concerns, perceptions, attitudes and expectations
- ▶ trained/mentored to understand and utilize the technology to its fullest extent.

What this means is that, when new technology is imposed on receiver organizations without ensuring internal receptivity, it is bound to fail. A very real factor influencing technology transfer is employee attitudes or resistance to change, also referred to as the 'not invented here syndrome'.

Once again, the case study on impact ripping emphasized the need for both educating the workforce to 'sell' a new technology to them, and then training them in the use of the new technology.

Integration process factors

Integration of technology with the rest of the system is essential for maximum benefit. Integration requires effort and resources going well beyond technology acquisition and training. The optimum performance of technology is obtained by redesigning and restructuring the entire system in which it is utilized.

The case study on impact ripping illustrates that throughout the history of the development of mechanized mining, the technique that proved most successful in the mining application was that one which was more easily integrated into the mining cycle.

Technology-push vs. Demand-pull

Allowing the researcher or developer to set the research agenda unilaterally so that the dominant relationship

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consists of either the researchers pushing their results onto product developers or product developers pulling work out of researchers creates an unhealthy situation.

However, most technology-based interaction between the technology source and the user organization makes use of market-pull mechanisms. This market- or technology-pull is more likely to result in successful interaction because the technical problem or opportunity is located within the user organization.

Despite the advantages of market-pull technology transfer, one should not lose sight of the fact that new technologies, particularly breakthroughs, have emerged through technology push, e.g. the use of nuclear energy. A balance between technology-push and market-pull is therefore important.

Communication factors

A significant number of technology transfer problems can be attributed to ineffective information exchange among technology sources, potential users and intermediaries. A considerable amount of attention should be given to reducing communication barriers.

A current weakness within South Africa's mining industry is the lack of communication strategies specific to the different developed technologies.

The nature of new technology

The most important aspect of technology transfer is the nature of the technology. The more concrete the technology, i.e. the extent to which the technology is understandable, demonstrable and unambiguous, the greater the probability of success. People-embodied technologies are therefore more difficult to transfer than product-embodied technologies.

The relevance of the project to the receiver organization's needs, interest in the subject matter, project goals and demonstrated usefulness of research results will have a huge impact on the transfer process.

Best practices derived from the literature survey

A number of best practices were derived from the literature to address the factors above, and as recommendations for future steps. They should not be regarded as foolproof recipes, but more as beacons directing technology transfer.

Perceived value/benefit of the technology

People who make decisions about acquiring technology for organizations do not choose technology *per se*; they choose the beneficial results of the technology. The developer and the user have to assess each other's needs and expectations and, more importantly, ascertain whether the technology is appropriate for the receiver.

An optimized technology transfer programme should promote activities that are highly regarded by both the industry and the research organization. In all the known successful cases, the technologies were highly recommended by respected authorities outside the transfer organization, i.e. a neutral party.

A culture supportive of technology transfer

The following human resources management practices have been associated with successful implementation of complex technology and an innovative working environment:

- ▶ Training of employees in terms of the new technology
- ▶ Gaining employee commitment to change by involving them in the technology transfer process from the outset
- ▶ Changing the infrastructure, structure and systems to cope with the anticipated changes
- ▶ Anchoring the new behaviour by adapting the reward system.

The importance of rewarding employees for using the new technology or procedures should not be underestimated as was clearly indicated in field trials of the hydraulic rock drills in the 1980s. However, the impact ripper case study also clearly highlights the need for *appropriately* rewarding employees, as in this case additional bonuses were detrimental to the technology transfer process.

Consultation and participation (interaction)

It is important to build/develop and maintain solid and respectful, long-term relationships among stakeholders.

Technology transfer as part of the strategic plan

A focused technology transfer strategy should broadly determine the direction of the organization's technology transfer effort and the criteria against which the effort will be appraised. A receiver organization's strategic plan would ideally be sufficiently well defined to identify the role technology transfer could play in achieving the organization's goal, to guide the search for new products/services by suggesting the types of markets and/or technologies to be exploited and those to avoid, to provide criteria for generating and screening new technologies, and to suggest ideas for evaluating the technology transfer.

Improved/optimized communication

Improved management of information exchange is required to increase the success rate of technology transfer.

It is important to realize that no single best recipe exists in terms of the media that are utilized. However, whatever the mechanisms used, reduce the information overload. Focus on the end user who is generally not interested in the R&D process or how a solution was developed. One should also keep in mind that active technology transfer, i.e. through transfer agents, proved more effective than passive efforts to disseminate information.

Evaluation and control systems

Technology transfer measurement and evaluation is a primitive science and is difficult to conceptualize. Some approaches are included in the following examples:

- ▶ Surveys to question technology recipients about the application of transferred knowledge
- ▶ Testimonials and positive anecdotal information.

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Various other techniques for measuring and assessing transfer efforts exist, for example:

- Transfer audits conducted by receiver organizations by way of client interviews at the end of every project
- In an operations audit, an *ad hoc* interdisciplinary team from the transfer agency performs a systematic audit of a client's operations

Training and mentoring

Training employees to understand and use new technology will have a direct effect on the capability of the employee to accept and implement new technology.

The principles associated with the application of the new technology remain unchanged for different users but the way in which they are presented and explained must be tailored to suit the end user. Trainers should be taught how to transfer skills and technology, deal with cultural differences and integrate the culture of the employees into the training programme. There is a need, therefore, to move beyond the translation of training material and to design training programmes that contain material relevant to the users.

It has been found that technical experts who learned to teach were more effective than a teacher who had to learn technology. As employees progress in their training, personal satisfaction and recognition by the organization and by peers will provide further incentive. Finally, mentoring is an essential ingredient of technology transfer. There is no substitute for learning from someone who has already been through the process.

Responsibilities of the role players

A number of role players in the technology transfer process have been identified.

Technology developer/researcher

Researchers frequently perceive the exchange of information as not central to the work they do. However, although they are not directly involved in the technology transfer process, they should be knowledgeable and enthusiastic role players in the transfer effort and must be kept informed of current policies and regulations and be encouraged to participate.

Researchers enhance the transfer of technology in a number of ways:

- They could communicate the importance of technology to an organization's representatives
- A large body of data exists in raw form written by inventors and usually in a manner that cannot be easily understood. The data should be transformed into information useful to the target audience
- Researchers should be responsive to the input and suggestions by industrial sponsors
- Technical staff should understand that results have to be usefully packaged, should focus on the end user's needs and should be presented in an easy-to-implement form
- Researchers should define research goals clearly because obscure or vague project goals could cause

disillusionment on the part of organizations who expected more from a project than was possible.

Technology transfer facilitator

The technology transfer facilitator acts as an intermediary between the developer of the technology and the receiver of the technology. In essence the technology transfer facilitator does the following:

- Takes care of the personal, organizational and cultural issues of recipients in order to achieve effective technology transfer
- Screens the environment for technological opportunities that could be translated into R&D projects
- Identifies a technology implementation champion in the receiver organization
- Emphasizes the relevance of the project to the organization's needs
- Demonstrates the usefulness of the research results
- Provides training sessions or seminars, giving potential implementers, users and researchers opportunities to interact
- Creates a climate in which problems may be addressed and solved at an early stage
- Develops and implements the technology transfer plan.

Implementers/champions

Although every technology to be transferred requires a champion on both the sending and receiving ends of the process, a champion is probably more important on the receiving side. The literature shows that a primary breakdown in the technology transfer process is not within the exchange of information, but at the point of implementation. In the South African mining industry, identifying champions can be complex, as senior staff on mines generally have a relatively short tenure on a mine as they are rotated amongst the mines. If a succession plan is not in place, the impetus in implementation may decline as the original urgency of the development is lost sight of.

The role of the implementer or the technology champion is highly complex. This person would be responsible for the following:

- Considers whether technological strategies are being planned and executed
- Coordinates R&D with strategic organization objectives
- Ensures that the top management team gains a better understanding of the technology transfer process as support for invention and innovation begins at the top
- Sees to it that effective communication takes place early and continuously throughout the life of a project and emphasizes personal interaction
- Acts as liaison between researchers and receiver organization employees
- Provides assistance with respect to implementing and training.

Finally, the champion is a person/team who understands technical aspects, who is familiar with human aspects and who can communicate effectively with end users or the workforce.

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End user

The end users are the people who would use the new technology on a daily basis. Their responsibilities lie in:

- ▶ verbalizing their needs
- ▶ keeping an open mind to change
- ▶ effectively listening to the information provided to them
- ▶ providing feedback on the technology and transfer process
- ▶ receiving appropriate training
- ▶ taking part in the change process.

Case study—impact mining systems—lessons learnt

The Impact Mining System (IMS) was under development for some 20 years. It underwent extensive pre-production trials in 1989 and 1990 and has been commercially available since 1991. From 1991 to 1992 four systems were purchased by a major South African gold mine and since then extensive full production trials were undertaken. These were suspended at the end of 1997.

The overall strategy for the IMS implementation was laudable and included most elements required for success. Its benefits were well communicated and demonstrated (through the pre-production trial), its design was well integrated into the existing mining system, extensive well documented training and maintenance manuals with job descriptions were prepared, detailed cost benefit analysis was undertaken, full and all encompassing monitoring and reporting was implemented and a champion was identified at the early stages of the project.

Its less than optimal performance during the full production trial was due to two main factors. Firstly, it soon became evident that the technology was not totally appropriate for the geotechnical environment in which it was installed. The IMS requires some weakness in the rock (usually mining-induced fractures) which it can exploit. In this case, there were large areas of 'hard patches', that is areas where no weaknesses existed. An extensive geotechnical investigation was not done prior to its introduction, which would have identified the problem. Nevertheless, such technical problems could be overcome by, for example, the introduction of a more powerful hammer. The fact that it was installed in the worst possible conditions was part of a philosophy of the time of 'if it works here it will work anywhere'. The converse of this is that if it does not work, the negative reputation gained slows down the rate of implementation and could even, in extreme cases, kill the technology.

Secondly, and much more importantly, human and organizational problems proved to be much more intractable with the following issues negatively affecting performance:

- ▶ Although initially there were champions, staff turnover resulted in these champions disappearing. The fact that champions tended to be situated in the Head Office environment meant that there was a powerful 'not invented here' syndrome on the mine

- ▶ The infrastructure and culture of the team remained the same as the rest of the mine. An appropriate culture for drill and blast mining was not appropriate for the IMS
- ▶ Training was always limited due both to a high turnover of all staff, and to the cutting short of training periods due to production pressures
- ▶ The knowledge held by the developer was not effectively utilized
- ▶ There was no effective independent technology facilitator to liaise with the equipment supplier, developer and the mine and to ensure technology transfer plans were implemented.

The trial certainly confirmed the validity of the factors that influence technology transfer identified in the theoretical study, particularly the dangers of introducing new technology in the production environment without first addressing the organizational and cultural issues.

Conclusions

In order to ensure that the South African mining industry maintains and improves its position with regard to competitiveness and to safety and health, it is essential that priority be given to successful technology transfer, that an enabling environment is provided in which to operate, that a thorough understanding of the benefits of technology transfer is instilled in all stakeholders and that key role players engage in building relevant capacity.

It is strongly recommended that the South African mining industry investigate the adoption of the best practices outlined in this paper by testing their feasibility among the various potential implementers/users in the mining environment. This would also involve comparing success and failure transfer cases to identify the relative importance of the best practices.

A number of role players with distinct responsibilities have been identified as integral to successful technology transfer. With the benefit of a technology facilitator having emerged so strongly, it is recommended that the industry promote this role player more strongly. Respected leaders in the mining industry should also take a more active role as champions of technology.

Another important factor that emerged was the need for a formal communications strategy in technology transfer.

Finally, the case study supported the view that, although technical problems are often blamed for technology transfer failure, they can be overcome relatively easily. However, if technology transfer is to be successful, the primary focus must be on the human and organizational factors.

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