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Technology Transfer, Adoption and Integration: A Review

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Abstract: Technology often needs to migrate from its place and culture of origin to other places through transfer/valorization/commercialization, innovation, adoption/diffusion and integration. This study defines these terms and relates them to one another. It discusses the technology transfer process, traditional and new models of technology adoption, technology adoption/diffusion participants and their characteristics, the needs of technology adopters, principles of networked learning environment, reward/recognition and technology innovation in educational community, the differences between the adoption of ICTs and that of previous technology innovations, theories of technology adoption and diffusion and adoption/diffusion versus integration of technology innovation in an institution's curriculum.

Key words: Technology transfer, ICTs, adoption, commercialization

INTRODUCTION

In the globalizing world market economy, driven by technology, including the Information Communications Technologies (ICTs), the transfer/valorization/ commercialization, innovation, adoption/diffusion and integration of technology have become more compeling. Countries that neglect these development strategies are simply lagging behind others (Eneh, 2008).

Rich but scattered literature materials are available and in many cases, aging (Rogers, 1986, 1995; Burkman, 1987; Moore, 1991; Stockdill and Morehouse, 1992; Farquhar and Surry, 1994; Geoghegan, 1994; Jaffee, 1998). There is the need to update and add to the literature on the subject. This study reviews and updates the literature on the subject. The rest of the study is structured as follows. Technology transfer (and its process) and the related valorization and commercialization concepts are discussed, followed by traditional and new models of technology adoption, technology adoption/diffusion participants and their characteristics, the needs of technology adopters, principles of networked learning environment, reward/recognition and technology innovation in educational community, the differences between the adoption of ICTs and that of previous technology innovations, theories of technology adoption and diffusion, adoption/diffusion versus integration of technology innovation in an institution's curriculum and conclusion.

TECHNOLOGY TRANSFER/VALORISATION/ COMMERCIALISATION

Technology transfer is the process of sharing skills, knowledge, technologies, methods of manufacturing, samples of manufacturing and facilities among governments and other institutions to ensure that scientific and technological developments are accessible to a wider range of users who can then further develop and exploit the technology into new products, processes, applications, materials or services. It is closely related to (and may arguably be considered a subset of) knowledge transfer. Related terms, used almost synonymously, include technology valorization and technology commercialization. Conceptually, the practice dates back to ancient times (Archimedes applied science to practical problems) (Wikipedia, 2001).

Technology transfer process: Many companies, universities and governmental organizations now have an Office of Technology Transfer (also known as Tech Transfer or TechXfer), which identifies researches with commercial interests and strategies for exploitation. A research result may be of scientific and commercial interest, but patents are normally issued for practical processes. Therefore, someone-not necessarily the researcher-needs to come up with a specific practical process. Commercial value is of essence over and above laboratory possibilities. For example, of the numerous ways to accomplish nuclear fusion, only those that generate more energy than they require to operate are of commercial value (and therefore, commercialisable) (Wikipedia, 2001).

The process to commercially exploit research varies widely. It can involve licensing agreements or setting up joint venture and partnerships to share both the risks and rewards of bringing new technologies to market. Other corporate vehicles, e.g., spin-outs, are used where the host organization does not have the necessary will, resources or skills to develop a new technology. Often

these approaches are associated with raising of Venture Capital (VC) as a means of funding development process, a practice more common in the US than in the EU, which has a more conservative approach to VC funding (Wikipedia, 2001).

Technology transfer offices may work on behalf of research institutions, governments and even large multinationals. Where start-ups and spin-outs are the clients, commercial fees are sometimes waived in lieu of an equity stake in the business. As a result of the potentially complexity of the technology transfer process, technology transfer organizations are often multidisciplinary, including economists, engineers, lawyers, marketers and scientists. The dynamics of the technology transfer process has attracted attention in its own right and there are several dedicated societies and journals. In recent years, there has been a marked increase in technology transfer intermediates specialized in their fields. This was stimulated in large part by the Bayh-Dole Act and equivalent legislation in other countries, which provided additional incentives for research exploitation (Wikipedia, 2001).

The white paper: The white paper is the document that should go with technology transfer. It is a comprehensive account of the technology creation process. It should be complete to the point that a reviewer should be able to make sense of the change with its assumptions, scope and context and have confidence in assigning resources to the new technology. All claims should be statistically validated through appropriate test, such as T-test and the like, which can easily be done on statistical software, such as JMP (Wikipedia, 2001).

The success criteria should be clearly spelt out to ensure that the technology has been transferred correctly, verified against success criteria. Also, equally important are the quality or process control measures, such as adequate SPC limits and rules that should be defined and followed. Process specification document needs to be attached (Wikipedia, 2001).

The white paper should also outline the people, who are the content experts and the committee member that approved the document. In summary, this document is a blue print of what is to be built. It should be as complete as possible to avoid misinterpretation and attendant costly mistakes. It should also be critically peer-reviewed by experts other than those doing the change (Wikipedia, 2001).

TECHNOLOGY INNOVATION, ADOPTION/DIFFUSION AND INTEGRATION

Technology adoption refers to the stage in which a technology is selected for use by an individual or an organization. Technology innovation is used with the nuances of a new or innovative technology being adopted. Technology diffusion refers to the stage in which the technology spreads to general use and application. Technology integration connotes a sense of acceptance and perhaps transparency, within the user environment (Carr, 2001).

Typically, past adoptions of a new technology for education have signaled a confidence in its potential to alleviate a particular problem or to make a job easier or more efficient; rarely has bringing about new social and functional conditions been a consideration. However, the ICTs may provide a means of creating totally new learning environments and it may be to that end that adoption is initiated. In such instances, innovation and adoption may be seen as virtually synonymous elements of the adoption/diffusion process (Carr, 2001).

The traditional and new models of technology adoption/diffusion: Various educational technologies were touted as revolutionary pedagogical wave of the future. Classroom films, programmed learning devices, language laboratories, educational television, computer-assisted instruction and, more recently, interactive videodisc technology have been adopted and integrated into the curriculum with varying degrees of success. Each technology was widely perceived as meeting a need and each gained a measure of initial commitment of resources from a high level administrative or legislative entity. Their adoption and diffusion process generally followed what has been termed the traditional model, a top-down process in which administrative mandate introduced the technology and administrative perceptions, decisions and strategies drove adoption and diffusion. Successful adoption was highly dependent on the degree, stability and wisdom of administrative sponsorship (Carr, 2001).

None of these technologies, however, has been generally available for individual or private use due to cost, scope or application. This deterred grass roots technology adoption cycle, as it was nearly impossible to generate movement from the bottom-up by influencing faculty peers and administrators with demonstrations of successful applications (Carr, 2001).

Today's education generation, however, sees the ICTs as technology's new wave. Distributed learning environments and distance learning with ICTs hold innovation at all levels and in all areas of education. The impetus for the ICTs innovation grows from individual users of the technology and as their communication and influence moves laterally through their contacts, a body of support can grow and exert pressure on the institutional administration to commit to adoption of the technology. There is, therefore, a high potential for a bottom-up or grass roots adoption/diffusion process to

succeed. Since, the ICTs is individual user-based in application, the adoption/diffusion process should start at that level. It should focus on the potential adopters and address their characteristics in the context of environment in which they will be using the technology (Carr, 2001).

The ICTs offers opportunities for creating new and significantly different educational applications. In addition to technological functionality and technical superiority, the hope in the education community that new ways of teaching and learning are made possible by the ICTs appears to drive its rapid adoption (Carr, 2001). On the other hand, resistance to Asynchronous Learning Networks (ALNs), which includes many ICTs-based learning applications is based on the perception of ICTs as a threat to the classroom teaching as an established practice and cultural tradition of the teaching faculty (Jaffee, 1998). To overcome this challenge to ICTs adoption/diffusion process, focus should be shifted to the potential adopter and the organization into which the technology will be integrated. An adopter-based, instrumentalist approach incorporating both macro- and micro-level perspectives is now most widely used to promote the adoption and diffusion of ICTs.

Burkman (1987) presented the user-oriented development approach consisting of 5 adopter-focused steps:

- Potential adopter identification
- Measurement of their relevant perceptions
- User or adopter-friendly product design and development
- Informing the potential user or adopter of the product
- Support after adoption

An alternative model (Stockdill and Morehouse, 1992) recommends a complete analysis of educational need and user characteristics along with the identification of a new educational technology's relevant and appropriate features and factors.

Carr (2001) stressed the need to analyse the environment in which the potential adopter is expected to use the technology, with a view to ensuring actual, correct and continual product use. This process includes identifying the relevant physical and use characteristics of both the instructional situation and the support system.

An adoption analysis approach (Farquhar and Surry, 1994) considers the process from the broader perspective of both user-perception and organization attributes, resulting in a plan for carrying out the adoption of technology that is rooted in an organizational context and addresses issues of concern to the intended user. Product and application design and development are also significantly influenced by this approach.

Technology adoption/diffusion participants and their characteristics: The traditional adoption/diffusion continuum recognizes 5 categories of participants:

- Innovators who tend to be experimentalists and techies interested in technology itself
- Early adopters who may be technically sophisticated and interested in technology for solving professional and academic problems
- Early majority adopters who are pragmatists and constitute the first part of the mainstream
- Late majority adopters who are less comfortable with technology and are the skeptical second half of the mainstream
- Laggards who may never adopt technology and may be antagonistic and critical of its use by others

The distribution of these groups within an adopter population typically follows the familiar bell-shaped curve (Rogers, 1995).

These groups are significantly different markets in the selling of an innovation to faculty adopters (Moore, 1991). Transition from the early adopters to the early majority adopters is essential to an innovation's success and offers potential for breakdown because the differences between the 2 groups is so striking (Table 1).

The needs of technology adopters: Addressing the needs implied by the early adopters-early majority adopters differences when addressing diffusion strategies can greatly enhance the likelihood that a technology will be successfully integrated into the curriculum by groups beyond the innovators and early adopters. Meeting these needs is an essential part of any successful diffusion strategy. According to Geoghegan (1994), the needs are:

Need for recognition and process involvement: The chances of successfully selling an innovation to the pragmatic early majority adopters will significantly increase if their differences are addressed in terms of their perceptions and needs. They should be recognized as a

Table 1: Characteristics of early adopters and early majority adopters of innovation

Early adopters	Early majority adopters
Technology focused	Not technically focused
Proponents of revolutionary change	Proponents of evolutionary change
Visionary users	Pragmatic users
Project oriented	Process oriented
Willing to take risks	Averse to taking risks
Willing to experiment	Look for proven applications
Individually self-sufficient	May require support
Tend to communicate horizontally (focused across disciplines)	Tend to communicate vertically (focused within a discipline)

Source: Adapted from Geoghegan (1994)

distinct group within the community and made part of the planning and policy making processes. Attempts to convert them to the point of view of the innovators and early adopters are likely to be futile, not to mention the certainty of disaster to result from imposing the technology on them. Diffusion of the innovation to the late majority adopters and laggards is more likely to occur through this early majority adopters' involvement, since the vertical lines of communication between the 3 groups are more direct than with the innovators and early adopters.

Need for vertical support structure to overcome technophobia: When adoption begins from the grass roots, innovators and early adopters, with their strong technology orientation, may be able to get by on their own initiative. Narrowly focused technical support staff may not pose a threat or discouragement to them and their needs for initial training and support may be relatively easy to accommodate. Early majority adopters, however, tend to have no interest in the technology per se and some may exhibit a form of technophobia. Their introduction to the technology should be related to their perceived programme and process needs. Since, they tend to focus vertically within a discipline, training and support provided by staff, who enjoy discipline/content credibility, will likely be best received. Correspondingly, such training and support will be more transferable to the late majority adopters and laggards.

Need for well-defined purpose or reason: The very existence of a technology may be reason enough for innovators and early adopters to pursue it. Their bent for experimentation and their innate interest in technology may dispose them to adopt it and be content with finding a problem to fit the solution. Early majority adopters (and others by extension), however, tend to derive their purposes from problems related to their disciplines. If the innovation can be demonstrated as an effective, efficient and easily applied solution to those focused needs, it is more likely to be adopted and integrated into the programme.

Need for ease of use and low risk of failure: The early majority adopters' aversion to risk quite naturally translates into a need for ease of use and early success if they are to adopt and diffuse the technology. The overlap with support and training requirements is obvious.

Need for institutional/administrative advocacy and commitment: In the top-down adoption effort, institutional sponsorship and support is a given. The innovation may be mandated and grant moneys or other funds committed. Without advocacy and resource commitment by the institution's policy setters and holders of the purse strings, other issues become moot as the process is likely doomed to stalemate, if not to an early demise.

But, innovation that occurs from the bottom-up also requires institutional attention and an administration as an entity (except for some possible rare exceptions) tends to emulate the early majority adopters rather than the innovators and early adopters. And, even when an institution initiates an innovation from the top, their perspective tends to be a pragmatic one based on a problem or need that a given technology promises to alleviate. It may relate to staffing, financing, scheduling, teaching, distance or communication. In any case, the mindset is similar to that of the early majority adopters and, as always, there is a need for advocacy to occur if the conditions and activities that can promote adoption by the early and late majority adopters and laggards are to prevail.

Principles of Networked Learning Environment (NLE): Several principles apply particularly to situations in which students and faculty are introduced to networked learning environments. According to Carr (2001), these principles (for ICTs) are:

First-time success: No one enjoys frustration or failure. An innovation is most likely to be accepted and integrated by the early and late majority adopters if success is experienced initially and subsequently built upon. E-mail is typically introduced early on because of its ease of use and its success is almost guaranteed. It also extends to peer network, both within and outside the institution, thereby magnifying its impact on adoption and diffusion.

On-going peer support: Complementing the experience of initial success, there should be ample hand-holding along the way of integration as other ICTs applications are introduced. Live peer support not only serves as assistance and encouragement; it contributes to the person-to-person communication that promotes diffusion throughout an educational community. In addition to a training cadre of recognized peers, a network of online mentors can expand the potential of the support structure to promote the exchange of innovative techniques.

Real task activities: The early and the late majorities are pragmatists who see technology in terms of real problem and task solutions. Activities designed to introduce and teach the technology should address those needs. Institutional administrations tend to emulate this

pragmatic perspective. Internet access to information and resource and its use for intra and inter-institutional communication can address many administrative needs in addition to those of the faculty, as well as establish a well-defined and recognizable need for adopting the technology.

Ownership and identity on the internet: Encouraging and enabling faculty and students to create an active presence on the internet is important. Participating in listservs, creating a personal home page, publishing electronic papers all contribute to the electronic world-community and help ease cultural assimilation. As with using e-mail to ensure early success with the technology, this presence extends the peer network impact on its adoption and diffusion. Beyond that, it also creates a professional identity and a credibility standing similar to that derived from traditional publication.

Variety of incentives: Attempts to impose a technology through explicit mandates and requirements, as in the top-down scenario, are not likely to be effective. This is particularly true with ICTs that is so generally available to anyone with the mindset to adopt it. Policies and procedures promoting the technology should grow naturally from its application and incentives for using it likewise should be tied to its practical use. Adoption/diffusion is more likely to occur where incentives and policies encourage a natural acceptance and use of the new technology.

Reward/recognition and technology innovation in educational community: Technology innovation in the educational community has often been hindered by the lack of a reward structure. Written publication has long been held as evidence of scholarly work that is worthy of recognition through promotions or tenure. In contrast, time consuming directed to pragmatic problem solving, instructional material design and development or innovative classroom teaching has rarely received similar recognition. Integrating a technology like the ICTs into one's teaching is time consuming and effort intensive, usurping time and energy that otherwise could be devoted to more traditional and more rewarded-endeavours. If innovative behaviour is to be sustained, there must be a recognised and acknowledged system of rewards parallel and equal, to that associated with traditional academic pursuits.

The differences between the adoption of ICTs and that of previous technology innovations: Rogers (1986) revealed 3 important ways in which the adoption of ICTs differs from that of previous innovations. For ICTs adoption

- A critical mass of adopters is required to convince the mainstream teachers of the technology's efficacy
- Regular and frequent use is necessary to ensure success of the diffusion effort
- ICTs is a tool that can be applied in different ways and for different purposes and is part of a dynamic process that may involve change, modification and reinvention by individual adopters (Carr, 2001).

Theories of technology adoption and diffusion: The top-down and bottom-up models of adoption/diffusion provide a directional perspective to the process. Another theory dichotomy relates to the scale of innovation efforts by distinguishing between macro-level theories and micro-level theories. The former focuses on the institution and systemic change initiatives. Innovation typically involves broad aspects of curriculum and instruction and might encompass a wide range of technologies and practices. Micro-level theories, on the other hand, focus on the individual adopters and a specific innovation or product rather than on large scale change (Carr, 2001).

Rogers (1995) presented 4 additional adoption/ diffusion theories. Each of these theories can be considered in the context of either top-down or bottom-up, macro-level or micro-level dichotomy. According to Carr (2001), the additional theories are:

Innovation decision process theory: Potential adopters of a technology progress over time through 5 stages in the diffusion process. They must

- Learn about the innovation (knowledge)
- Be persuaded of the value of the innovation (persuasion)
- decide to adopt it (decision)
- Implement the innovation (implementation)
- Reaffirm or reject the decision (confirmation). The focus is on the user or adopter

Individual innovativeness theory: Innovative people or risk takers will adopt an innovation earlier in the continuum of adoption/diffusion.

Rate of adoption theory: Diffusion takes place over time with innovations going through a slow, gradual growth period, followed by dramatic and rapid growth and then a gradual stabilization and finally a decline.

Perceived attributes theory: There are 5 attributes upon which an innovation is judged:

- That it can be tried out (trialability)
- That results can be observed (observability)

- That it has an advantage over other innovations or the present circumstance (relative advantage)
- That it is not overly complex to learn or use (complexity)
- That it fits in or is compatible with the circumstances into which it will be adopted (compatibility)

Carr (2001) talks of yet another adoption/diffusion theory dichotomy: the determinist (developer-based) focus and the instrumentalist (adopter-based) one. Determinists regard technology as the primary cause of social change. The technology adoption/diffusion process is seen as a series of revolutionary advances that are thought to be out of direct human control. The innovation's developer is viewed as the primary change agent. Focus is on an innovation's technical characteristics. Successful adoption/diffusion is the assumed result of an innovation's technological superiority.

For the instrumentalists, the technology adoption/diffusion process is evolutionary and the causes of change are in social conditions and in human aspirations for change and improvement. The focus is on the user (adopter) of a technology and its value as a tool to bring about desired change. Human control over the innovation is a key issue and it is considered essential to understand the social context in which it will be used and the function that it will serve.

Adoption/diffusion versus integration of technology innovation in an institution's curriculum: The adoption and diffusion of an innovation within an institution does not guarantee its successful integration into the curriculum or its continued use. Decades ago, the once ubiquitous classroom film was used in public schools as a Friday afternoon filler rather than a planned learning experience and lack of appropriate and adequate teacher training inhibited the full use of language laboratories in public schools. Therefore, if ICTs' glitz, popularity and apparent ease of use are allowed to preempt careful planning, or if teachers and students do not receive proper training in its use, its integration as an information and learning resource as well as a communication tool, will likely be subverted. Strong advocacy is needed to ensure that the conditions necessary for technology adoption and diffusion are put in place. Training in technical aspects and applications to real needs is crucial to a technology's integration beyond the innovators and early adopters. Time for experimentation and development of applications is essential. Successful peer users are needed to lead the technology's integration into the curriculum. If the technology is perceived as difficult to learn and/or too time-consuming to prepare and use, or is in some other way perceived as threatening, it probably will not be used. Institution's administration needs to nurture a perception of value in terms of needs/problem solving and academic or other rewards through establishment of policies, incentives, recognition and online presence in the internet culture and environment (Carr, 2001).

CONCLUSIONS

No nation is an island unto itself that has no need of other nations. In the globalizing world market economy, all nations are important and need one another. A glaring area of this need is technology transfer/valorization/commercialisation, adoption/diffusion and innovation, integration. Nations that disregard these strategies are lagging behind in development. This review paper has attempted to define, relate to one another and discuss these strategies.

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