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Title: **Technology Assimilation Proficiency-Reflecting Graduate Attributes: A review of the literature on mining engineering practice and higher education in South Africa**

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CONTEXT

Technology assimilation (TA) is both a technical matter and a social process. The importance of TA emanates from the fact that it is a necessary condition to the industrialization, economic development, and social upliftment of nations or communities. People, either in their roles and activities as engineers, technicians, innovators, marketers, or as other participants, are intimately involved with and in the process of TA. The study investigates people attributes that reflect, or are associated with, TA proficiency. Furthermore, the study seeks to understand the core aspects within which such attributes manifest in mining engineering practice and higher education in South Africa.

PURPOSE

The study focuses on understanding how TA is understood in engineering practice and higher education in the South Africa. It also seeks to identify TA proficiency-reflecting graduate attributes that are required and valued, and the contexts within which these manifest, in mining engineering practice and higher education in South Africa.

APPROACH

The current study is the first stage of an envisaged two-stage investigation. All data and evidence in the current paper was sourced from reviewed literature. Due to the limited, if any, published materials on the topic, specifically as it pertains to South African contexts, a thematic approach was used rather than a systematic literature review.

The SA mining sector employs large numbers of graduates from the mining, electrical, mechanical, and mechatronic engineering disciplines. Attempts were therefore made to understand the documented TA-related contexts, roles, experiences, and activities of these four disciplines in the mining industry and higher education in South Africa. Furthermore, attempts were made to identify TA proficiency-reflecting attributes required and valued in such contexts.

TA is generally misunderstood in both engineering practice and higher education. An overall understanding of TA was established through critical analyses of the multiple perspectives on TA, and then synthesizing the reviewed literature into major themes.

ACTUAL OUTCOMES

A taxonomy of the factors that influence TA was developed. The taxonomy comprises two categories of '*Technology content-specific factors*' and '*TA process-related factors.* Furthermore, a preliminary list of TA proficiency-reflecting attributes was also compiled.

KEY WORDS

Technology Assimilation (TA); Graduate Attributes; and Taxonomy of Factors

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1 Introduction

Technology assimilation (TA) presents various benefits to an organisation, such as operational competitiveness and market share changes (Wolfe, 1994; Bozeman, 2000; Jie et al., 2015), as well as benefits to society, in the form of regional or national economic development and other socio-economic impacts (Rogers, 1962; Hlavacek & Thompson, 1973; Menghetti, 2002; Jie et al., 2015). However, when done poorly, TA can lead to un-recouped capital investment and unrealised operational competitiveness (Rogers, 1962; Hlavacek & Thompson, 1973; Menghetti, 2002; Jie et al., 2015). The process of TA can be slow, disruptive, and costly. Assimilation rates can vary across countries or organization, thus resulting differences in developmental outcomes and experiences (Holdom, 1989). It is therefore imperative to identify and develop the necessary TA proficiency-reflecting skills and competencies such as to avoid the negative outcomes of poorly implemented TA projects.

TA is a reality in engineering practice in South Africa. Many old and new technologies have been unsuccessfully adopted in many engineering fields (Menghetti, 2002; Sahin, 2006), including in the SA mining industry. Moreover, some technologies are initially adopted by an organization, but then disrupted or discontinued before organization-wide, comprehensive, effective assimilation is realised (Jie et al., 2015). The outcomes of unsuccessful, disrupted, or discontinued adoption can be mitigated through the identification and development of TA proficiency-reflecting attributes.

Increasingly, higher education in South Africa is seen as a contributor to the economy "through the production of skilled graduates" (Winberg et al., 2018: 234). This entails the attainment of graduate attributes (i.e., programme outcomes) (Winberg et al., 2018). Graduate attributes are generally viewed as the skills, knowledge, competencies, practices, cultures, and values fostered within higher education (Barrie, 2006; Jones, 2009; Bond et al., 2017; Anderson, 2017). The South African Council on Higher Education (CHE) points out that graduate attributes are "oriented towards different disciplines and fields", and that they also "encompass values, attitudes, critical thinking, ethical and professional behaviour, and the capacity of a graduate to take what has been learnt beyond the site of learning" (CHE, 2013:19). Furthermore, South African universities are required to identify appropriate graduate attributes and implement these across programmes (CHE, 2013). Graduate attributes (GAs) are therefore the link between a student's academic performance in higher education and post-qualification employability (Winberg et al., 2018).

2 Understanding TA

The literature contains a vast number of theories covering the subjects of technology, innovation, assimilation, and the determinants associated therewith. However, the subject of 'technology assimilation (TA)', on its own accord, has not been adequately explored. There is also very limited direct empirical data available about the process of TA. Misunderstandings pertaining TA are further exacerbated by the multiple perspectives on the subject. These perspectives are primarily influenced by disciplinary and methodological orientations.

In this paper, some simplifying assumptions regarding the complex process of TA can be explained through, amongst others, the integrated combinations of some aspects of *technology transfer theory* (TTT), *technology acceptance model* (TAM), and the *diffusion of innovations theory* (DIT). These theories and models are not synonymous to TA but are similar or analogous to TA in some respects.

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3 Research question

The study focuses on how TA is understood in engineering practice and higher education in South Africa. It attempts to establish an understanding by leveraging on TA-related contexts, experiences, roles, and activities in which graduate engineers are involved, in the South African mining sector and in higher education. It is hoped that TA proficiency-reflecting graduate attributes can be identified from understanding the contexts and activities in which the process of TA manifests.

The goals and focus points of the study are summarised in the research question below:

Focal research question: What does the literature suggest are the core aspects to be considered in understanding technology assimilation (TA) in mining engineering practice and higher education in South Africa?

To address the focal research question, the study aimed to collect data and evidence from published literature to accomplish the following:

- Establish how TA is understood in mining engineering practice and higher education in South Africa
- Identify TA proficiency-reflecting professional engineering attributes required and valued in mining engineering practice.
- Identify TA proficiency-reflecting graduate attributes (also known as 'exit level outcomes') fostered in higher education (if any) in South Africa.

4 Actual outcomes of the study

The outcomes of this study are as outlined in the subsections below

4.1 Synthesised perspective on the TA process

The synthesized perspective is premised on TA process as referring to the way technology or innovation diffuses across organisational activities, projects, or work processes, and then becoming routinised and embedded in those activities (Fichman & Kemerer, 1999; Purvis et al., 2001). It is reliant on the distillation of the concepts of *technology*, *invention*, and *innovation*, which are explained by a few authors, such as Rogers (1983), Eveland (1986), Fichman & Kemerer (1999) and Utterback (1971). A technology comprises *hardware aspects* and *software aspects*. Both the hardware and the software aspects of technology encompass knowledge (Rogers, 1983; Cordey-Hayes & Gilbert, 1996; Zahra & Gerard, 2002; Gonzalez, 2015), and therefore require proficiency and, more importantly for this study, assimilation. An invention is an original, newly created device or process. An innovation, on the other hand, is an invention that has been a subject of entrepreneurial action to give it economic significance. Therefore, TA essentially entails the introduction of new technology or innovation – such as new products, methods, procedures, machines, processes, or theory into the operational activities of an organisation, or a social system, for the purpose of realising some economic benefits. It is a process reliant on two integral, intertwined elements of *technology*, and *the people*.

The core aspects of the synthesized perspective on TA are as depicted in figures 1 & 2 below. TA is a process that takes place in stages – from '*basic research & innovation*' to '*impacts and social consequences of innovations'*. However, the process may not necessarily be unidirectional due the re-designs and adaptations that a technology may be subjected to

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in the interim stages. Furthermore, the various stages are interactive and overlap one another. Due to micro- and macro-mechanisms, the individual stages, and the overall process of TA, are often iterative.

Figure 1: Summarized perspectives on the process of technology assimilation

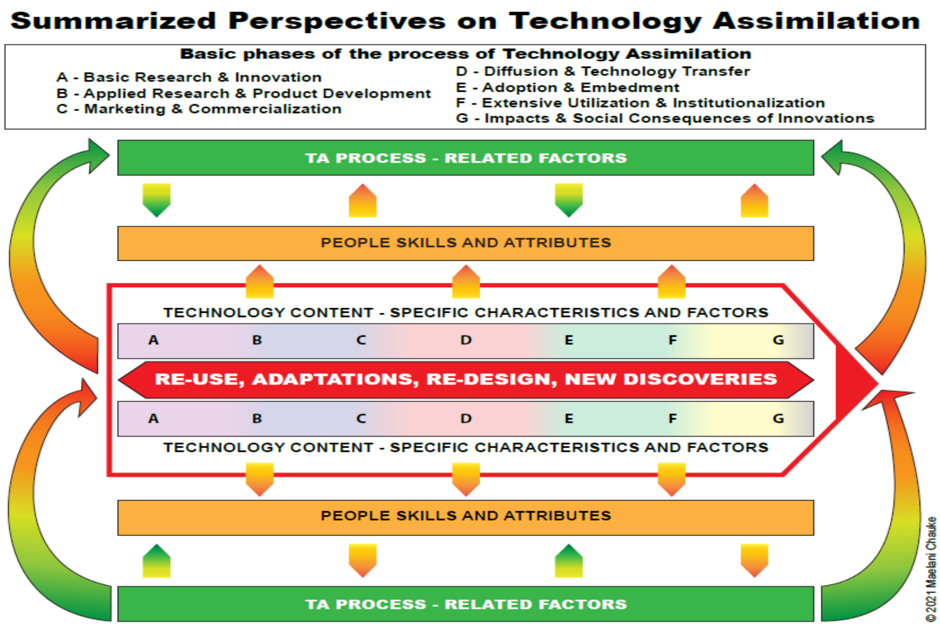

Figure 2: Taxonomy of factors influencing the process of technology assimilation

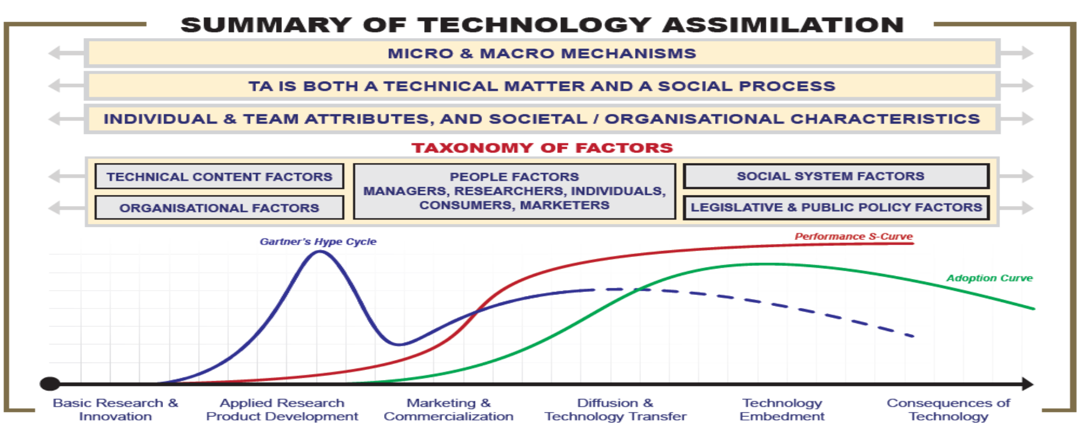

Figure 1 also emphasises the indispensability, and inseparability, of both '*technology content-specific factors*' and '*TA process-related factors*' in the overall of TA process. Both categories of factors are influenced by '*people skills and attributes*'.

Figure 2 depicts the various stages of the TA process in relation to the well-known '*Gartner's Hype Cycle*', the '*Performance S-Curve*', and the '*Adoption Curve*'. Each of the curves gives

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an approximate trajectory of, or impacts, on '*technology content-specific factors'* or '*TA process-related factors*' over the entire envisaged process of TA. The figure also emphasizes the centrality of *people factors*, and the associated *people skills and attributes*, over the entire process of TA.

4.2 Taxonomy of factors that influence TA

TA is a technical matter as well as a social process (Rogers, 1983). Furthermore, micro-, macro- mechanisms and sub-processes are involved in the overall TA process. More importantly, factors that inhibit or enhance the process of TA cannot be considered independently of the contexts within which they manifest. These factors, which were synthesised from the literature, are divided into two categories viz. *technology content-specific factors,* and *TA process-related factors*. The former includes factors, aspects, and characteristics such as *technical aspects*, *technological aspects*, *physical characteristics*, *utilitarian aspects*, *technology-specific knowledge and expertise*, and *infrastructural requirements* of a technology. The latter category, on the other hand, includes *organizational* factors, *people factors*, *social system factors*, *legislative and public policy factors*. Furthermore, TA proficiency-reflecting attributes are integral to all factors that influence TA, and to the overall process of TA.

4.2.1 Technology content-specific factors

The manner and extent to which a practical need or want is addressed is encapsulated in the technical, technological, physical, instrumental, ergonomics, or utilitarian characteristic or aspects of a technology (i.e., *technology content-specific factors*). In other words, a technology must satisfy technology content-specific requirements in other to qualify as an appropriate, relevant, effective technical means of addressing an identified practical challenge, need, or want. In essence, the initial success or failure of the TA process is influenced by the suitability of '*technology content-specific factors'* in satisfying an identified practical need. This study attempted to identity TA proficiency-reflecting attributes that are required and valued in South African contexts, as regards the potential ability to satisfy 'technology content-specific' requirements of projects or work activities.

4.2.2 TA process-related factors

*Organizational factors***:** Empirical research has demonstrated that organisational factors such as organisational structure, information, communication, and infrastructure enhance or constrain the process of TA (Rothwell & Robertson, 1973; Bayer & Melone, 1998; Wong et al., 1998; Armstrong & Sambamurthy, 1999). For instance, structural arrangements such as cross-functional teams, project matrix, and balanced matrix have been found to achieve higher assimilation success rates than either purely functional teams or hierarchical structures (Wong et al., 1998). Networking and flexibility brought about by modern information technologies have also been found to enhance TA (Wong et al., 1998). This study attempted to identify TA proficiency-reflecting attributes that are required and valued in South African contexts when dealing with organisational factors-related challenges.

People factors: People play critical roles in both their individual and organisational capacities (e.g., as managers, researchers, innovators, marketers) in the process of TA (Meyer & Goes, 1988; Bayer & Melone, 1988; Fichman, 1992; Bozeman, 2000; Zhu et al., 2006). Therefore, it is important to explore TA by taking into consideration the contributions and contexts of human systems (Eveland, 1986). More specifically, individual and people team attributes influence

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the success or failure of the process of TA. This study focused on the identification of TA proficiency-reflecting attributes that required and valued for dealing with people factors.

Social system factors: A social system comprises a set of interrelated units (people) that are engaged in joint problem solving to accomplish a common goal (Rogers, 1983: Wenger, 1998). Moreover, a social system constitutes a boundary within which an innovation diffuses (Rogers, 1983; Bozeman, 2000). Social structure, which gives regularity and stability of human behaviour in a social system, refers to the patterned arrangements of the units of a system (Rogers, 1983). Furthermore, information regarding the established patterns of behaviour (i.e., norms), beliefs, values, and attitudes of a society flows through social structure. Social structure, and other characteristics of a social system, also act as barriers or enhancers to the process of TA (ibid). Social system factors, amongst others, include power relations and the social consequences of TA. New graduates, for instance, operate within new social system factors (i.e., as separate, and distinct from higher education) in their new place of employment after the completion of their academic careers. From TA perspective, this study seeks to identify TA proficiency-reflecting attributes that are required and valued for dealing with social system factors.

Legislative and public policy factors: A country's legislative, regulatory, economic, and public policy frameworks influence the internal and external milieus within which an organization conducts its activities (Bozeman, 1994; Bozeman, 2000; Rogers et al., 2001). Empirical research has, for instance, demonstrated that the combination of regulatory and economic policies that allow for the transfer of technologies from national sources (e.g., government–owned national R & D laboratories or research universities) to private companies can provide the basis for economic growth of metropolitan regions (Rogers et al., 2001). Furthermore, combinations of 'cooperative technology policy' and 'taxation incentives', have also been empirically found to encourage intra and cross-sectional innovation and technology transfer (Bozeman, 2000; Rogers et al., 2001). TA projects are executed within the boundaries of different legislative and public policy frameworks (e.g., different from one country to another). This study thus attempted to identify TA proficiency-reflecting attributes that are required and valued for dealing challenges emanating from '*legislative and public policy factors'*.

4.2.3 Technology - and TA Proficiency-reflecting Skills and Attributes

The successful execution of any TA project depends on the satisfaction of, or compliance to, the relevant '*technology content-specific factors'* and '*TA process-related factors',* both of which are influenced by *people skills and attributes.* Technology is only one aspect in the overall process of TA. Although they may share some similarities, '*technology proficiency-reflecting attributes*', are different from '*TA proficiency-reflecting attributes*.

A preliminary list of '*TA proficiency-reflecting attributes'* was compiled in the study. The list consists of the attributes of *critical technology awareness*; *engineering creativity*; *innovation (skill)*; *digital literacy*; *knowledgeability/communication*; *continued professional development* (e.g., *life-long learning)*; *nuanced attributes collection*; *entrepreneurship; and teamwork.*

In the list above, the '*nuanced attributes collection'* includes skills and competencies such as *emotional intelligence, adaptability and flexibility, reflections on learning, curiosity, resourcefulness, independence, reflexibility, self-awareness*, and *resilience*.

All the listed 'TA proficiency-reflecting attributes' display various aspects of '*context-dependency'*, and thus require adjustment or mutation subject to a particular situation. Therefore, the effective employment of these skills sets is also dependent on the ability to customise and realign them to any new situation.

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5 Conclusions and recommendations

Despite limited published material on the topic of this paper, a thematic approach as adopted herein, can nevertheless help in exploring the topic.

The process of TA can be understood as summarized in subsection 6 and depicted in figures 1 and 2 above. The core aspects of TA are incorporated into the categories of '*technology content-specific factors'* and '*TA process-related factors'*. The successful execution of any TA projects entails the satisfaction of, and compliance to, the requirements of aspects and characteristics outlined under *technology content-specific factors'* (e.g., utilitarian characteristics – subsection 4.2.1), and 'TA process-related factors (e.g. using TA-appropriable structural arrangements in organizations – subsection 4.2.2).

'Technology content-specific' and 'TA process-related' category factors are both integral to the process of TA. Therefore, the development of TA proficiency-reflecting attributes cannot be skewed towards one category to the detriment of the other.

Due to limited published material of the topic, the applicability of TA understanding established in this paper, particularly as pertain mining engineering and higher education contexts in South Africa, could not be determined. The same applies to the factors that enhance or inhibit TA, and the TA proficiency-reflecting attributes.

It is recommended that the second stage of this study, and other similar studies, be used to collect empirical data and evidence which can be used to determine the relevance and applicability of the outcomes of this paper to mining engineering practice and higher education in South Africa.

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