Knowledge Ecosystems in Higher Education: Implications for Universities of Technology in South Africa

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More than ever, modern society increasingly relies on universities to develop technologies for today's knowledge economies. In order to facilitate the transfer and diffusion of technologies, many universities develop university spin-offs (USOs) as vehicles for technology transfer. The American model for USO development, for instance the 'Silicon Valley' and the 'Route 128' has been very successful. In South Africa and many other developing countries, however, USO formation is still limited despite the availability of diverse skills within universities. As a result, sustainable technology transfer in developing nations is difficult to realise. In this paper it is argued that knowledge ecosystems that stimulate the interchange of information, knowledge, and expertise invariably promote USO development. Thus, drawing from lessons from the experience from other countries, as well as the specific South African settings a conceptual model for stimulating the USO formation is presented.

INTRODUCTION

As modern society increasingly looks toward higher and advanced education for solutions, universities are fast transmuting into agents and engines for development (Ismail, 2008; Mellors, 2006). This is especially so in the developing world, were colleges and universities have since graduated from mere centres for learning into development agents, and are increasingly involved in socio-economic initiatives including poverty reduction and employment creation (HESA, 2010). This paradigm shift, at least in developing nations, appears to be driven by the "increase in demand for knowledge in today's knowledge economies" (Ismail, 2008). Thus, the 'new' university specialises in creating and transmitting knowledge (Du Pre, 2009).

Universities perform three basic functions: teaching, research, and community engagement (Duderstadt, 2000). Teaching involves instruction in the various disciplines such as accounting, marketing, philosophy, psychology, and economics. Research, on the other hand, concerns itself with developing, and sometimes, the testing of theory. Lastly, community engagement considers all other activities involving universities' stakeholders, for example fund raising for a local hospital or conducting adult literacy classes.

Early universities focussed only on teaching. Little attention was placed on research and even less on community activities. However, the modern university concept redirects attention to community-centred institutions (Mellors, 2006). Since the 1990s community engagement has become the focal point of higher education. More specifically how and what can institutions of higher learning contribute to local communities, through teaching and research (Du Pre, 2009; HESA, 2007; 2010; Mellors, 2006). And within the context of a developing nation like South Africa, universities may prove most significant by participating in poverty alleviation, employment creation, and improving access to health care (HESA, 2007). The implication for universities is to focus on creating and transferring innovations that address societal challenges including poverty and unemployment.

The potential for technological innovations are enticing, however, these can only be realised when they are successfully transmitted. For example, the life-saving qualities of antiretroviral (ARVs) will only be beneficial if the drugs are distributed to HIV/ AIDS patients. Thus, the diffusion of technologies is equally important as their creation. It is only through the former that communities benefit from technological advancement. It is against this background that in this paper we argue for efficient modes of diffusion of technological innovations or technology transfer. Because universities are knowledge and information repositories (Duderstadt, 2000), this paper considers only technological innovations generated at institutions of higher learning. In this respect, several authors recommend commercially spinning out technologies through university initiated businesses or university spin-offs (USOs) (Du Pre, 2009; Gubeli & Doloreux, 2005; HESA, 2007; Pirnay *et al*., 2003).

For that reason, the South African government affirms the importance of technology transfer and considers it a national priority. Hence the inception of R&D initiatives such as Tshumisano Fund and National Research Fund (NRF) to support university research (HESA, 2007). Overall, these initiatives have been successful in meeting their objectives. For example the underwater fibre optic project at Stellenbosch University or the bone grafting procedure at Tshwane University of Technology. Save for a few examples, diffusion of these innovations remains low, as few technological innovations ever leave university laboratories. On the whole, South African universities are grappling with developing vehicles for diffusing innovations. Although USO formation in the developed world appears to successfully enable technology transfer, in South Africa, especially among the universities of technology (UoTs), USO formation still remains limited. Therefore this paper argues that technology transfer is best mediated through USOs.

Despite UoTs are abounding with diverse skills, ranging from accountants to lawyers to technologists and scientists, harnessing this expertise in forming USOs has proved to be problematic. Accordingly, we further argue that USO formation is facilitated by an open interchange of knowledge and information among students, faculty, financiers, and stakeholders organised within knowledge ecosystems.

In order to facilitate presentation of these arguments, a brief analysis of the South African higher education sector is presented so as to set the study in a wider context and root it within a particular context. Following on, technology transfer is discussed. Then, USO concepts and trends are analysed, and these culminate into a framework that UoTs may apply in developing knowledge ecologies. Subsequently, limitations and conclusions are presented.

THE SOUTH AFRICAN HIGHER EDUCATION SECTOR

The South African higher education sector consists of 23 public universities. Of which 11 are traditional universities, 6 are comprehensive universities, and 6 universities of technology as well as 94 privately registered colleges and institutes. Combined university enrolment exceeds 750, 000 students (Council on Higher Education, 2000). With the advent of democracy, the sector is continually adapting to the demands for a new South Africa (Du Pre, 2009; HESA, 2007; 2010). One notable change was the creation of Universities of Technology (UoTs) (Council on Higher Education, 2009b; Higher Education South Africa, 2007). Previously UoTs or the former *Technikons* catered only for the black majority, and as a result had limited access to other institutions of higher learning. Because of this special preserve, UoTs' campuses tend to be situated in communities previously reserved for Black Africans, the majority of the population. In the yesteryear, UoTs' locations limited their accessibility and subsequently their consequence on national development. However, in the new and democratic South Africa, UoTs' physical locations may potentially be their greatest asset in terms of social and economic development. Because technology transfer seeks to promote social and economic development, in South Africa UoTs, more than any other institution of higher education, have the greatest potential for initiating development. UoTs' student population is most representative of South Africa's demographic profile, in terms of race, gender, ethnicity, and income classifications (Council on Higher Education, 2009b). Thus, they make a viable case study for investigation.

Universities of Technology (UoTs)

UoTs were created when the former *Technikons* (or polytechnic colleges) merged with traditional universities (Du Pre, 2009). In total there are 6 UoTs, namely the Cape Peninsula University of Technology, Central University of Technology, Durban University of Technology, Tshwane University of Technology, and Vaal University of Technology (Council on Higher Education, 2009b). Although they are the least represented, approximately 25%, they are the fastest growing and most adaptive (Council on Higher Education, 2009b; Du Pre, 2009).

Historically, UoTs are biased towards developing technical skills, and enjoy a long-established relationship with industry. Collaboration between the two is commonplace; students attend apprenticeship training in industry. In turn, industry sometimes commissions research on new processes and ideas to the former *Technikons*. Thus, for the purposes of this studying UoTs is ideal for a number of reasons: (a) proximity to the population's majority and potential for mediating development, (b) most adaptive of all universities, and (c) close ties with industry. Overall, UoTs have the greatest potential for both technology development as well as its dissemination.

TECHNOLOGY TRANSFER

A classic example of technology transfer is the invention and subsequent diffusion of gun powder. The technology was developed in China (technology generators), but it was the Europeans (technology recipients) that transformed its use for world conquest (Li-Hua, 2006). Equally, the case of the magnetic train technology illustrates the role of technology transfer in modern society. Both technology generators and recipients have the ability to develop competitive advantage from technology transfer. Shanghai was able to create the fastest commuter train (500 km/h) from the magnetic train technology developed in Germany. On the one hand, the Germans retain patents to the technology, and on the other hand, the Chinese benefit from this efficient mode of transportation.

Technology transfer is the process by which new knowledge is transformed into usable innovations, inventions, and products (HESA, 2007; Li-Hua, 2006). The ultimate objective of technology transfer is to discover solutions to specific problems. It is this problem-solving ability that makes technology transfer a crucial factor for social and economic development (Li-Hua, 2006).

In universities new knowledge is created primarily from research activities, and through USOs this knowledge permeates into the economy (Gubeli & Doloreux, 2005). For instance the emergence of the "Silicon Valley" phenomenon in the United States, which has, as a result, reshaped American higher education. USOs have become a permanent feature and are both a process and product of higher education. Consider Google,[1] a product of Stanford University students, is one of the more successful USOs. Its innovative products – Internet search-engine, Gmail, and Facebook resulted from technology transfer, and today have forever transformed the Internet and communication.

To qualify as technology transfer, Gubeli & Doloreux (2005) contend that developed goods and services should satisfy two basic requirements. First, their origin stems from some form of research. Secondly, these goods and services must provide tangible benefits to both the developers and end-users. Users should derive some kind of use value that ultimately translates into economic value for the inventors (Ma *et al*., 2009). As with the Google example, Google Inc.'s multi-billion enterprise has increased the net worth of its founders. On the other hand millions of individuals benefit from services such as Gmail, Facebook, and Google, among others. These have become so popular so much so that they introduced new words into the computing language. For instance, "googling," which refers to the process of searching for information on the Internet (Dictionary.com, 2010). It is this research aspect that makes universities an essential element of technology transfer.

Universities and Technology Transfer

The relevance of universities' participation in technology transfer is best illustrated in the following excerpt, from an interview collected by Dr. Marguerite Robinson, an anthropologist, in Indonesia in the 1970s. As she was collecting the interview, an elderly gentleman commented:

> We are pleased that you are interested in us, that you visit our houses, and that you sit and talk with us. We try to tell you whatever you want to know. But we would like to ask a question. There is something that we cannot understand. We are sitting here in the mud because this is all we have. Can you not see that we are cold and wet, and that we are poor and have nothing? But you are educated and wealthy. Why do you want to sit here and learn about our customs? Why do you not also use your knowledge and resources to help us to have better lives and improve our customs (Robinson, 2001)?

Dr. Robinson confesses that the above-mentioned interview was an epiphany. It exposed academia's obliviousness to its duty of servitude to society. However, universities can through technology transfer use 'knowledge and resources' to improve society. For that reason, Marguerite Robinson (2001) seems to argue that university education lacking technology transfer is not only inadequate, but it is also meaningless, as traditional classroom teaching and learning is too static for the 21st Century digital economies (Shrivastava, 1999). HESA (2007) further argue that modern economies require research organisations, including universities, to continually learn new knowledge and disseminate it for value creation, as espoused by Gubeli & Doloreux (2005). This is in line with Mellors' (2006) modern universities' community engagement paradigm that posits universities to be developmental catalysts (HESA, 2010). Thus, it is not a question of whether universities should engage in technology transfer, but a question of how.

According to the Association of University Technology Managers (2005), the earliest university technology transfer initiatives were recorded in the US in the early 1970s. Since then, technology transfer has dominated the academic landscape; 'Silicon Valley' and 'Route 128' are common examples (Pirnay *et al.*, 2003). Mellors (2006) agrees and affirms that universities' value to society has since increased. Because of the utility of university-driven technology transfer, many cities in the UK frequently bid to host university campuses (Mellors, 2006). For that reason, technology transfer is now an integral part of higher education. While technology generation is initiated by research, technology diffusion is promoted by private partnerships and knowledge ecologies (Shambare & Nekati, 2009) that eventually culminate into USOs (HESA, 2007; Pirnay *et al.,* 2003;).

Solving Real and Complex Problems

In order for universities to engage meaningfully in transmitting knowledge, Zuber-Skerrit and Fletcher (2007) recommend the use of action research methodologies, as ordinary methodologies have limitations in devising practical solutions (Zuber-Skerrit & Perry, 2002). Basic and academic research are important and often are precursors to the former, they are concerned with the development of theory. It is this theory that usually is tested in the real world, by other means such as action research. Action research combines both academic and applied research approaches and focuses on solving real-life problems as well as contributing to the body of knowledge (Zuber-Skerrit & Fletcher, 2007). This real-world thematic concern or the ability to solve real world complex problems makes it a viable methodology, especially in the social sciences, for technology transfer (Zuber-Skerrit & Perry, 2002). Such an approach enables 'action' intervention. According to Li-Hua (2006), this connection between academics and practitioners enables knowledge transfer, which in turn catalyses technology transfer. On this, the discussion moves o to USOs.

University Spin-Offs: Technology Transfer Vehicles

The term university spin-off or USO refers to any new firm or business created to exploit commercially some knowledge, technology, or research results developed within a university (Pirnay *et al.,* 2003). Implicit to this definition are the following (Pirnay *et al*., 2003):

(a) ***New company:*** a USO is a separate legal entity and not an extension or a subsidiary of the university. It is fully autonomous.
(b) ***Created from universities:*** the parent organisation is exclusively universities and excludes other education or research institutions.
(c) ***To exploit knowledge produced by academic activities:*** this includes all technological innovations, intellectual property, scientific, and technical know-how acquired at a university.
(d) ***Profit-oriented:*** the purpose of the USO is to maximise profits, just like any other business entity.

In agreement, Rogers and Steffenson (1999) define a USO as an entity created from the fusion of human capital, intellectual capital, and financial capital arising from a university. Further, Gubeli and Doloreux (2005) argue that the presence of an entrepreneurial culture within the university is an important enabler for USOs. In addition, Roberts and Malone (1996) identify four key principles instrumental in the development of USOs. These are:

(1) The technology originator – individuals or organisation that nurtures the technology from basic research to a point where its transfer can take place.
(2) The university usually acts as the owner of the intellectual property (IP), and therefore regulates spin-off activities.
(3) Entrepreneur(s) formulate a business model
(4) The venture capitalists or investors that provide financial support for new company.

Roberts and Malone's (1996) principles suggest networks to be inherent in USO development. Such networks, on a bare minimum, should incorporate people or organisations instrumental in forming USOs. These are: (a) university students and graduates, (b) faculty, (c) university administrators, (d) financiers and investors, (e) researchers, and (f) community of entrepreneurs. Ultimately, as indicated by Li-Hua (2006), knowledge transfer or the interchange of knowledge and information among these stakeholders results in cooperation and subsequently the formation of USOs for mutual benefit.

Thus, universities' pivotal role is to assemble these different groups of people within knowledge ecosystems (Por, 2000) and to regulate their interaction thereof (Shambare & Nekati, 2009). It is through knowledge ecologies that the various USO stakeholders converge. It is through knowledge ecosystems that USOs are formed, and it is also through these ecosystems that value addition to technological innovation takes place. Overall, knowledge ecosystems harness the power of networks and networking.

KNOWLEDGE ECOSYSTEMS

As with any ecology, interconnections among entities provide life support functions – be it energy in biological ecologies or knowledge in knowledge ecologies (Pickett & Cadenasso, 2002). For the purposes of clarity, we specify the definition of knowledge ecosystem as the collection of relationships, tools, and methods for creating, integrating, sharing, using, and leveraging knowledge. Increasingly many business organisations have devised knowledge ecosystems as expert networking forums to facilitate knowledge transfer (BNI International, 2008; Shrivastava, 1999).

The Conceptual Framework

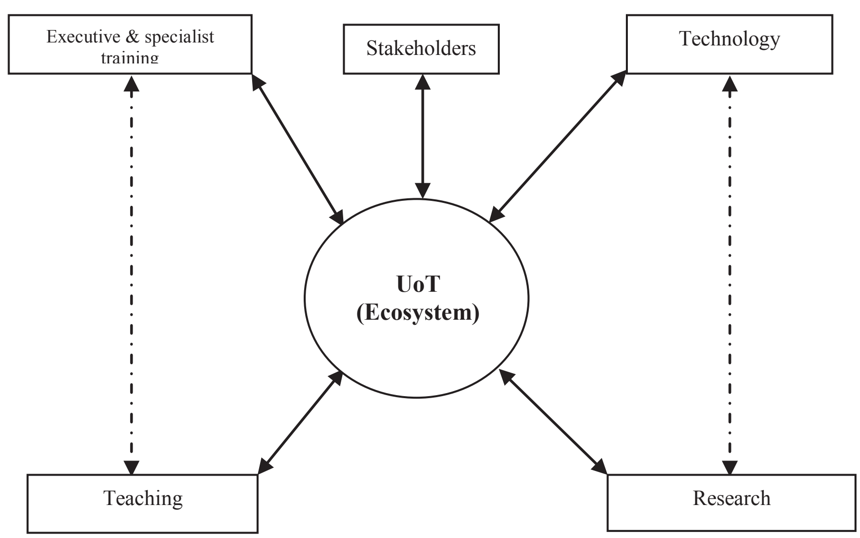
The South African higher education is yet to reach a critical mass of spinning out technological innovations. More specifically, because of their nature, UoTs present the greatest potential. To this effect, we have developed a framework that potentially may guide UoTs' participation in developing spin-off enterprises.

Unique to UoTs are three basic principles that separate them from other institutions. These are (a) cross-linkages industry, (b) community engagement, and (c) technology focus (Du Pre, 2009). As already indicated, Tshumisano and NRF programmes have resulted in much technological innovations. What is lacking, however, is the diffusion of these technologies, hence, USOs.

While a number of strategies are employed to achieve technology transfer. This study considers USOs (Gubeli & Doloreux, 2005; Pirnay *et al*., 2003) for two reasons. Firstly, given the high unemployment rates in developing countries, USOs are also likely to provide employment opportunities for university students and graduates. Secondly, with increased entrepreneurial activity on the part of students and communities, much poverty is likely to be alleviated. We developed the conceptual framework (see Fig. 1) using foremost, personal experience working with research centres and incubators at Tshwane University of Technology.[2] In order to make sure that key factors were not excluded, we incorporated insights from relevant research, which was followed up by qualitative interviews with senior personnel from two UoTs – Tshwane University of Technology and Durban University of Technology.

The university is the convergence point for any spin-off activity. On the lower half of the conceptual model, the two university functions of teaching and research are presented. On the upper half, the stakeholders or the community of the institution are depicted. These are connected to the university through a specialist network. The network fully emerges as a knowledge ecosystem when it is connected to the university environment of students and faculty.

FIGURE 1
FRAMEWORK FOR DEVELOPING UNIVERSITY SPIN-OFFS



University Functions

In this regard, the university performs three basic functions: research, teaching, and business development.

Research

Through research, UoTs generates new technologies, innovations, and processes. To a certain extent, research focus ought to be informed and guided by both institutional priorities as well as societal needs.

Indirectly, the research function is represented in the ecosystem through technology and innovations. In addition, the institution also provides financial and other non-monetary support for research activities.

Teaching

The teaching function contributes more towards soft skills. These include managerial practices, contacts, partnership agreements, development of various business tools, including business and marketing plans. Teaching mostly applies to formal degree programmes, but in addition to this, executive and specialist will also be provided for informal programmes specifically designed to equip candidates with specific tools. Duration of these usually ranges from 1 day to 12 months. For instance, a 3-day Business Plan writing Workshop.

Business Development

Business development takes a leading role in the ecosystem formulation. This becomes the conduit through which the institution can interact with third parties for and on behalf of the university. Ideally, such a unit must be a private company wholly owned by the university in order to free it from bureaucracy as well as dispel any fears of misappropriation of taxpayers' funds. The department interacts with stakeholders and financiers as well as with students. It identifies the market needs and searches for innovations available within the university. Thereafter, a suitable model among the stakeholders is formulated. Although the department may initially be funded by the university, it should be able to operate sustainably through revenue from executive programmes as well as intellectual property rights.

Ecosystem

The ecosystem is a highly specialised network of groups of peoples from different backgrounds and the more diverse the cluster is the better. In these networks, the following should be represented:

(a) From the UoT, the following:
- *University students and graduates:* ideally a register of research projects undertaken by postgraduate students should be maintained. This research can be classified into research focus and niche area, which may facilitate identifying interdisciplinary research projects.
- *Faculty:* comprising lecturers, research supervisors, and promoters. By promoting cooperation among faculty, students will also be encouraged to work together closely.
- *Administrative departments:* universities are bureaucratic institutions, and often lack coordination among departments, especially between teaching and non-teaching departments. Involving support personnel from finance, legal, and marketing streamlines processes.

(b) From the community, the following:
- *Financiers and investors:* investors, bankers, and venture capitalists are always on the watch for brilliant business ideas to finance. Maintaining close ties with these individuals or organisations improves chances of securing funding.
- *Community of entrepreneurs:* in developing business ideas and subsequently successful businesses, students may require mentorship. Thus, local businesspeople may be willing to act as mentors.

DISCUSSION

Knowledge ecosystems are vehicles catalyse the flow of information within the university, among the various departments, and with the university and the community. The point of departure therefore is first to encourage coordination between students (from different disciplines – law, business, psychology, and engineering) and their instructors. At this stage, students are able to bring together their diverse skills towards achieving common goals. For example, a new innovation may be developed by engineering students, law students prepare all the necessary legal aspects, and entrepreneurship students formulate a viable business model. Throughout this process, instructors and business development personnel provide tools and guidance and regulate the flow of work. Specifically, university departments could contribute the following in the creation of knowledge ecologies:

Faculties of Education

Education schools may participate by improving the quality of teaching and learning by engaging in research in the practice of pedagogic practice (Prince *et al.,* 2007). Increased discourse in the area enables the creation of forums for sharing best practices in education. With improved teaching techniques, for instance practical learning, students are more likely to apply as well as share their newly acquired skill and knowledge.

Faculties of Science & Engineering

Their participation is biased towards technology generation. Accordingly, students from engineering schools should increase interaction with manufacturing firms so as to gain appreciation of both practical and theoretical aspects in process and product development.

Faculties of Business

Business students concern themselves with discovering sustainable solutions to the various aspects of business and business processes. Thus, their focus should be directed from the current theoretical one to that of practical training. Students should acquire experience of handling real-life situations. This includes students not only learning, say, how to draft business plans, but to also attempt forming small scale businesses from the business plans. Business students become more active in the formation and formulation of USO business models.

LIMITATIONS AND CONCLUSIONS

In this paper, we concluded that modern universities specialise in creating and transmitting knowledge, also known as technology transfer. We also learnt that technology transfer promotes socio-economic development, and that USOs are the best approach to transmit technology from universities to the community. Although this has become the common practice in most developed countries, in South Africa however UoTs are grappling with spinning out technologies. Albeit numerous technological innovations developed at UoTs, the number of USOs is still limited. To that effect, we propose a framework that South African UoTs may follow in order to promote USO development.

First, collaboration between university departments, both academic and support, must be harmonised through a central agency, which we identified as the business development agency. In order to appeal to both the university population and the wider community, the latter office ideally should be a private entity owned by the university, for a number of reasons. First, because of institutional bureaucracy most private companies desist from doing business with government institutes such as universities. Secondly and also related to bureaucracy, processes are streamlined to operate efficiently. Thirdly, transparency among all stakeholders is promoted.

Second, with the business development agency in place and operating as a profit-maximising organisation, it should then form partnerships with the community. Thus, by knowledge ecosystems are formed by bringing together students, staff, entrepreneurs, financiers, and mentors. The mutually beneficial relations of ecosystems culminate into USOs.

The study is delimited to include only UoTs in South Africa. As such, results may not necessarily be applicable in other contexts. Overall, the concept of USOs appears to provide solutions to a number of challenges faced in developing nations. USOs potentially may have a positive impact on poverty alleviation and employment generation. The implication for policymakers and educators alike is focusing on fostering collaboration between industry and education, as synergistic partnerships between the two are unavoidable. What is, however, more critical, is managing the silo mentality prevalent within academia. To conclude, it would be interesting for further research to subject the developed model to testing. Additionally, potential challenges of USO formation from other factors, such as students' willingness to initiate these ventures as well as financing issues including the community's willingness to support USOs could also be considered.

ENDNOTES

1. Google was formed in 1998 by two Stanford University students with collaboration and funding from venture capitalists.
2. TUT is the biggest, in terms of student enrolment and programmes offered, of the 6 UoTs in South Africa.

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