Engineering Education and Regional Economic Development

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Abstract

The Free State is the second poorest province of South Africa. Hence, Central University of Technology decided to implement a programme to contribute to the socio-economic upliftment of the region. An institutional structure, the Unit of Technology and Innovation (T&I), has been established to stimulate innovation by staff, students and industry and oversee the efforts of a range of institutional entities at commercializing research outputs, assisting entrepreneurs in the development of new products, and facilitating the incubation of new start-up enterprises. These efforts are integrated into the academic enterprise, as prescribed by an overarching institutional document, Vision 2020. The Centre for Rapid Prototyping and Manufacturing and the Product Development Technology Station are institutional units overseen by T&I operating in this environment. Jointly they strive to avail product development expertise and facilities to local entrepreneurs. A general purpose incubator, as well as tooling incubator, was also established to ensure the availability of a one-stop support unit for entrepreneurial staff, graduating students and industry to develop and commercialise products. A business model was developed for these units whereby their services could be availed to industry, facilitating the financing of the extension of their collaborative technology base in a self-sustainable manner.

Keywords
Commercialization, Incubation, Manufacturing, Product Development, Socio-economic development.

1. Introduction
Central University of Technology, Free State (CUT) is situated in the second poorest province of South Africa's nine provinces. Hence there is a dire need for socio-economic development in the region with an opportunity for CUT to play an important role in this.

CUT has accepted, through its different governance and management structures, the institutionally defined Vision 2020: Creating an "isle of innovation" (CUT Strategic Execution Unit, 2011) as the guiding principle for its development in the foreseeable future. According to this document CUT should by 2020 be a university which focuses on creating social and technical innovations with a positive impact on socio-economic development in the region. Herewith CUT undertook to embark on an active approach to realize socio-economic development as the final outcome of its (research) endeavours. This is perfectly in line with a national priority as indicated by the South African National Planning Commission (National Planning Commission, 2011).

This article describes the current situation with respect to innovation and technology transfer at CUT and summarizes institutional structures created in support of meeting the criteria set in Vision 2020. A supporting system has been developed and implemented to realize the above, where such a system can be perceived as a grouping of individual parts with a particular relationship between them (Holzbaur, 2010). This is linked to the fact that education and research at CUT is practiced around graduate profiles defined by industry, with the focus on applied research into professional practice (Lategan, 2009).

It has been found by successful developing countries that the buildup of innovation capacities must take place early in the development process in order to facilitate innovation at a technological level aligned with local needs (OECD, 2012) making use of appropriate, available technology.

In order to convert newly developed knowledge – irrespective of its source - into some commercial success it needs to be converted into socio-economic solutions. Obviously the extent of commercial success derived is determined

by the developers' ability to facilitate this conversion as well as the novelty and value addition of the potential product or process.

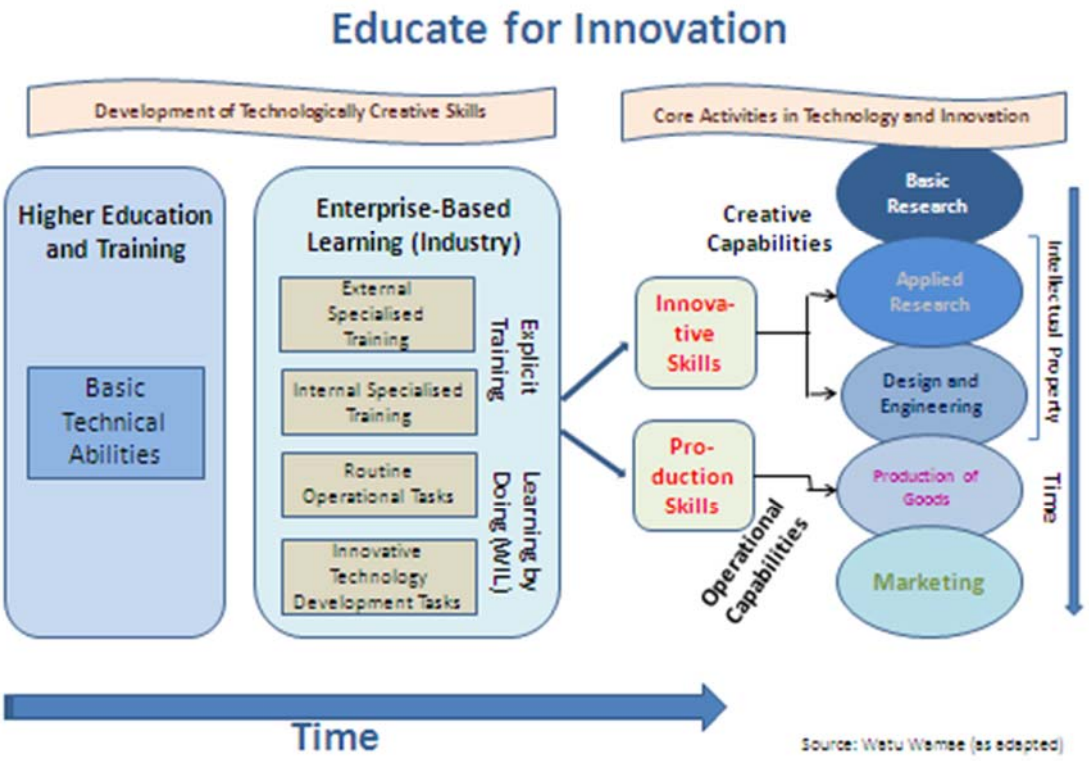

Figure 1: A model of education for innovation as practiced at CUT (Wamae, 2011, as adapted), showing the relationship between the different educational activities in the intellectual development of students.

The principles of preparing staff and students for innovation in a technological academic environment can be considered as two complementary processes, viz.:

- Development of technologically creative skills, and
- Development of core skills for innovation and technology transfer.

The relative position and timing of these two fundamental elements of the educational process are illustrated in Figure 1.

2. Development of Technologically Creative Skills

Students acquire specialized technical skills whilst undergoing education and training in a higher education institution. This enables the studying, understanding and eventually development of relatively complicated practices and processes. Such knowledge acquisition takes place in the classroom, laboratory, library and during interaction with lecturers and fellow students. The ability to interact creatively within any discipline normally develops over a period of time during advanced level studies and, after completion of studies, in an industrial environment.

Graduating students normally find employment at an enterprise in the field of his or her studies. Employees of larger enterprises are usually also expected to attend a variety of external specialised short courses. At these they are exposed to different forms of specialized technical and non-technical training.

Through such activities, as well as exposure to normal, routine operational activities in industry, the technical – largely theoretical - knowledge that students acquire during their studies are enhanced with relevant practical skills.

The intensity and combination of formal and informal training individuals are exposed to, as well as their individual creative aptitude, significantly influence the probable success that they would have in innovative activities.

3. Development of Core Skills for Innovation and Technology Transfer

Students and graduates usually develop particular innovative and operational skills during their training. However, depending on their individual characters and aptitude, different individuals tend to be more inclined towards either innovative or operational activities. Hence it is often found that, depending on the nature of their employment and practical exposure, employees with the same education tend to become predominantly involved in either one of these – usually without the total exclusion of the other.

3.1 Innovative Skills (Creative Capabilities)

These skills are critical for the creation of a new design, process or service, as well as the ability to manage such a development process. They represent a particular link between the technical capability to develop a new system, and the characteristics of the technologies that are available to produce it. Without this link the ability of any individual to successfully develop a new device is seriously curtailed.

3.2 Operational Skills

This typically comprises production, maintenance and operational skills, required for the successful production and maintenance of goods, processes and services. Individuals who are especially well-suited for this type of work might not necessarily be very successful in more creative activities.

4. The Innovation Process

The innovation process can be shown as in Table 1, where distinction is made between the (a) innovation and (b) commercialization of a new product:

Table 1: The different primary steps in the innovation and commercialization process.

A. Innovation	1.Idea Formulation
	2.Product Development
	3.Industrialisation
B. Commercialisation	4.Manufacture
	5.Marketing
	6.Assess Market Acceptance

However, the outcome of innovation seldom represents a fundamental technological breakthrough. Rather, it is typically an incremental step on a continuous stream of related products or services. Hence, successful innovation necessitates a good understanding of the current status of available products and the deficiencies of such. Questions concerning the relevant manufacturing processes, potential market value and its acceptability to its users are to be studied. Any further development should add value – where value is the ratio of the resultant benefit to the product's cost - to the present range of products. Only now should any real work on the development of a new idea begin – especially if it will supplement any existing product or process. This process is depicted in the innovation circle below (Figure 2).

Initially, virtually all effort should go towards researching the technical solution of a problem. In this manner the idea is expanded upon and concretised, whilst being further researched in an iterative process and a comprehensive, optimal solution developed. The solution that is arrived at in this manner will be industrialized by considering its manufacturability with the available, or at least realistically available manufacturing infrastructure. It is important to note that careful consideration should be given to the repeatability of the operational characteristics of the proposed design since any changes thereto, once the manufacturing sequence has been finalized, is extremely expensive and may sink the complete project. Hence, the importance of adhering to multi-phased iterative principles during the developmental process.

Once a final solution to the problem has been arrived at and before it becomes part of the public domain, steps might be taken to protect any intellectual property developed in this process. This may take the form of patenting - preliminary, final and/or international patents may be taken out, depending on the estimated value of the development – or design registration.

Figure 2: Innovation usually takes place in an incremental manner, hence the innovation steps shown in steps 1 and 6 in table 1 above could be seen as a circular process.

At this time the technical elements of the problem have been solved comprehensively and almost all attention should be shifted to the commercialisation of the product.

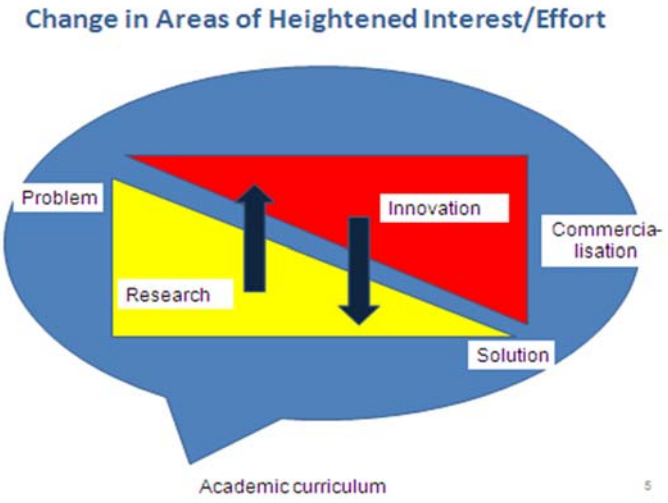

Figure 3: There is a gradual shift in effort from solving the underlying technical problems during the research phase, towards commercializing a new product or service during the commercialization phase.

5. Cut Structures in Support of Innovation and Technology Transfer

CUT has created an extended series of operational units to ensure the involvement of staff and students in commercial activities in the interest of the university, its staff and students, an in particular to ensure extensive contact of the academe with industry. This greatly enhanced the professional standing of the CUT in industry and contributed to providing staff with opportunities to stay abreast of technological and industrial developments. Figure 4 shows the basic structure and reporting lines of these entities.

The Office of Technology and Innovation is nominally in charge of the different units shown in this figure, whilst the staff of the Department of Mechanical Engineering are involved in a research niche area in Integrated Product Development and technologically support the operations of the other commercial units shown when required.

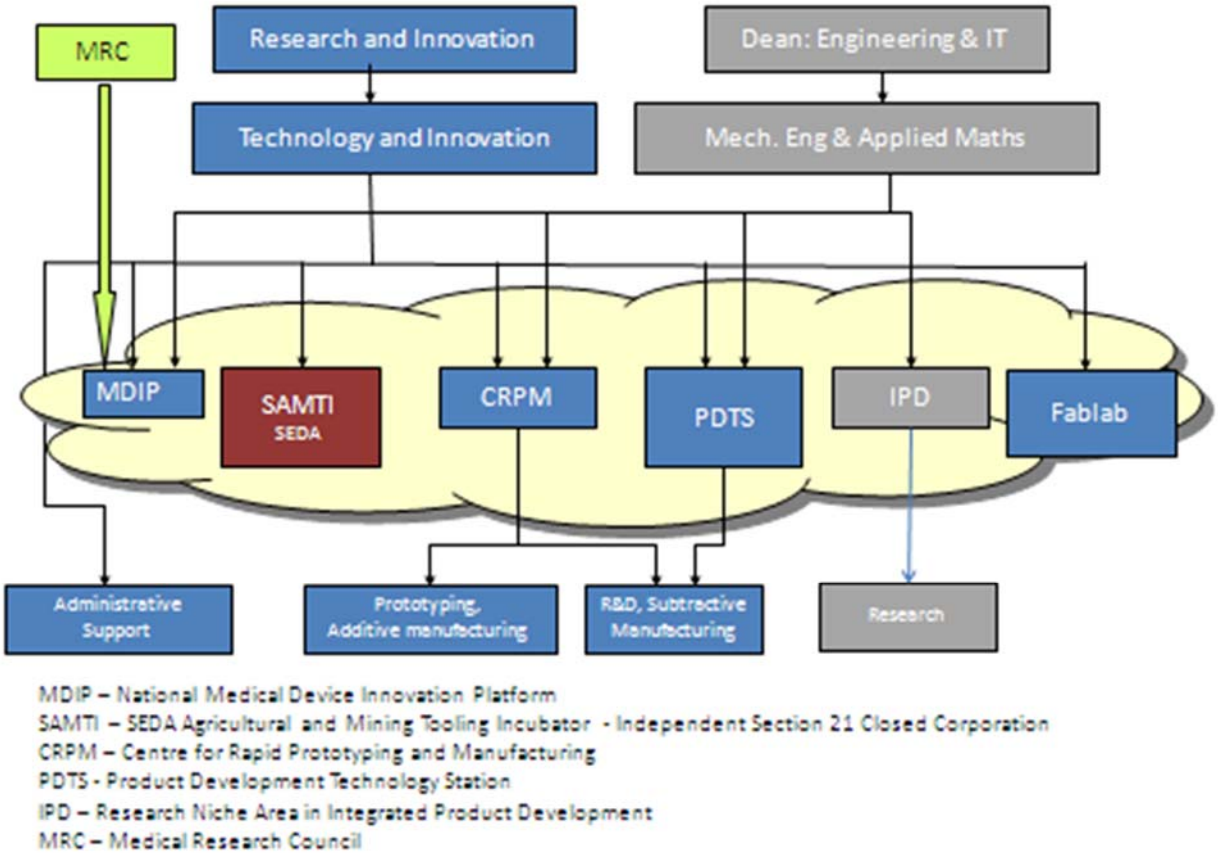

Figure 4: Institutional structures at CUT supporting the local industry in enhancing manufacturing capabilities and outputs and contributing to socio-economic development.

In this manner any research outputs created in the relevant department, and/or the commercialization centres shown, are assessed for possible commercialization, intellectual property thereof is registered (protected) if applicable and possible industrial development executed by the most relevant structure shown above, or by a combination of these units. Alternatively the IP is licensed to external bodies.

Entrepreneurship has been defined as the implementation of a business idea by combination of innovation and rational management (Binkauskas, 2012). Hence, the importance of technological, as well as managerial/financial skills, for the successful creation of a new start-up enterprise aimed at the development and marketing of a new product, process or service cannot be overstressed and should receive serious attention.

5.1 Product Development Technology Station
Similarly new product development processes are followed to develop new products on behalf of external customers under a formal system of subsidization with respect to such expenses. This development work is executed primarily by the PDTS, a unit established under the South African Technology Stations programme and financed by the national Department of Science and Technology. The PDTS is managed primarily by a technical Director, two design engineers, four junior design engineers and a number of interns. The operational staff are engineering graduates of CUT who showed an interest and aptitude for innovation during their studies. Approximately 80 projects are completed annually for external entities. These customers range in size from major motor vehicle manufacturers to new start-ups.

5.2 Centre for Rapid Prototyping and Manufacturing
The Centre for Rapid Prototyping and Manufacturing (CRPM) has ten different additive manufacturing technologies utilizing a wide array of different materials to "grow" products on a layer-by-layer basis. In this manner prototypes for evaluation of form and function, limited run final products and tooling inserts can be manufactured in different materials, including types of plastic and nylon, sand, maraging and stainless steel, and titanium. CRPM delivers service to approximately 500 clients and executes approximately 400 projects per year with a total value of approximately 400,000 euro. Amongst its customers are the PDTS, MDIP and SAMTI (discussed below).

The operational procedures according to which the CRPM operates ensure that it can finance the rather expensive maintenance of its additive manufacturing infrastructure, as well as the gradual expansion of its range of technical facilities. In addition components to a value of approximately 10% of the centre's commercial income are grown at no cost, specifically on assignment for researchers in the different departments of the Faculty of Engineering and Information Technology. This resulted in a situation where in excess of 80% of the research outputs of the Department of Mechanical Engineering is the result of work done in the CRPM.

The CRPM is the sole owner of additive manufacturing equipment in the Free State. Hence it is able to contribute significantly to the needs of the local industries. It also houses the only technology able to grow implants in Titanium for medical research purposes.

5.3 Medical Device Innovation Platform
The MDIP, a founding member of the national Medical Device Innovation Platform which is financed by the South African Medical Research Council, is primarily involved in research and the design, development and (additive) manufacture of personalized, experimental medical implants and surgical supportive devices in conjunction with the CRPM.

5.4 Seda Agricultural and Mining Tooling Incubator
The Free State province used to be particularly strong in terms of gold and diamond mining, as well as agriculture. Even though the level of activities in mining in currently decreasing, the Small Enterprise Development Agency, a national body involved in the establishment of new businesses, agreed to sponsor the establishment of SAMTI on campus as well. The SAMTI is an independent entity, financed by the national Department of Trade and Industry through the Small Enterprise Development Agency (Seda) that incubates new start-ups in the manufacture of tooling for agriculture and mining. It is situated on the main campus of CUT and most of its infrastructure is the property of the university that is conditionally availed to the incubator. This enabled the establishment of the incubator and ensuring access to modern facilities at minimal cost. Due to its particular operational position in the structure of CUT, the Office of Technology and Innovation acts as liaison between the university and SAMTI.

5.5 CUT Incubator
The potential value of a successful incubator in supporting the creation of new start-up business entities and the resultant employment opportunities and wealth creation is well known. It is always beneficial to include large corporations in an incubator (Krzysztof). Yet a small incubator, housing a few new start-up enterprises – without a large tenant - is also functioning under the guidance of the Office of Technology and Innovation at CUT. This unit is also aimed indirectly at improving the socio-economic situation of the region. Unfortunately only nine offices/workshops are at present available for participants in the local incubation programme, hence an alternative system of virtual incubation is also engaged in. Last mentioned is primarily evident in the form of new start-ups making use of the services of the PDTS to develop new devices or services. These entities are often in need of business training and advice which is availed via the CUT Incubation Programme. A few entities that were started

in the incubator have progressed beyond the means of the incubator and are relatively successful with annual turnovers in excess of 500,000 euros.

5.6 Protection of Intellectual Property

The Office of Technology and Innovation is also responsible for the monitoring and execution of South African Act 51, 2008 (Intellectual Property Rights from Publicly Financed Research and Development Act, 2008). This act prescribes the handling of intellectual property (IP) developed by universities and statutory councils which are financed by the national Government. In this manner any staff member or student of such an entity legally qualifies for profit-sharing in terms of the eventual income of the university or science council received as a consequence of IP created.

6. The Way Forward

CUT management and its council have recently decided to establish the so-called CUT Services and Enterprises Trust as its commercialization arm. The intention is that this unit, which is to function independent from the university except for reporting to its council, should be responsible for the commercialization of any IP registered in the name of the university. Since this is a new structure the value of its establishment and roll-out is still unclear.

At Central University of Technology (CUT) the possible launch of an Innovation and Incubation Programme (IIP) to support researchers with financing the development of new products and processes once the viability of such has been proven through formal research has recently been approved. Researchers could therefore now apply for support from the IIP for final applied research and industrialization required to enable formal commercialization of new products, processes or services.

The national Department of Science and Technology (DST) is quite active in the establishment of a number of Regional Innovation Centres (RIC) in South Africa with the objective to:

- Assist regions in evaluating and developing their systems of innovation;
- Facilitate the establishment of mechanisms for local innovation;
- Align regional innovation strategies with national industrial and innovation policies, and
- Build capacity for regional innovation strategy development (Department of Science and Technology, 2009).

Hence, with the support of DST the university has embarked on negotiations regarding the possible establishment of an RIC. Substantial levels of collaboration between the two universities in the region, the Provincial Government, industry and non-governmental organizations are expected to flow from this arrangement – which is to be financed largely by the National Government.

In spite of its best efforts the Government has thus far been unable to ensure the provision of sufficient employment opportunities for the inhabitants of the country – especially with an unprecedented influx of illegal immigrants from elsewhere in Africa. Hence an unemployment rate of above 25% (approximately 49% in terms of continuous, formal employment) is still in evidence, causing poverty and hardship, as well as incidences of violence against foreigners in the recent past. This situation serves as additional motivation for CUT to try and contribute to the resolution of unemployment and to contribute indirectly to wealth creation.

7. Summary

This article does not represent a theoretical study, but is a case study of initiatives taken by Central University of Technology, Free State in support of socio-economic development of the Free State province in South Africa. A wide range of complementary structures have been established by the CUT to render a joint positive effect on the socio-economic development of a region with limited technological resources and a net outflow of expertise.

To facilitate a substantial level of synergy and cooperation between these units, the Office of Technology and Innovation has been assigned the responsibility to manage these units in the interest of the university and the region in general, whilst ensuring the registration and safeguarding of IP developed by CUT staff and students. In addition the limited capacity for incubation has been leveraged by a supplementary supportive system of off-campus virtual

incubation. In this manner a larger group of start-up enterprises qualify for access to professional business advice and guidance by suitably qualified and experienced individuals.

The exact impact of the combined effect of all the above efforts by CUT to positively affect the socio-economic impact of the region has not yet been researched, yet there has been a significant increase in the number of intellectual property applications for statutory protection that flowed in the recent past. Without exception these could be linked to contributions made by some of the support units discussed above. There is also significant evidence that an entity such as CRPM positively affected the acceptance by the South African manufacturing industry of additive manufacturing. This is borne out by the fact that CUT acquired the third such machine in South Africa fifteen years ago – whilst being ridiculed at the time by the relevant industry for wasting its money on such "useless" technology – whilst, at the last count, no less than 342 such machines were being used by the same industry in South Africa at present. In addition several outputs of the support units have since been commercialized successfully.

The outflow of the above structure, and its contribution to the experience of engineering students, serves as significant evidence that by a moderate change to educational practice can have a significant effect on the potential contribution such graduates can have on the socio-economic development of the region.

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Biography

Gerrit Jordaan is Director: Technology and Innovation at Central University of Technology (CUT). As such he oversees the functioning and strategic development of several commercial activities of the University. He is a professor and the holder of a DTech in Electrical Engineering from CUT. He published several journal and conference papers, and contributed to several text books. His research interest includes product development, additive manufacturing and automated material-handling technologies, and successfully supervised in access of 20 masters and doctoral students. He is also a student of innovation, commercialization and incubation activities.