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The role of the university in the field of nanotechnology : the case of the University of the Witwatersrand.

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CHAPTER ONE

1. INTRODUCTION

1.1 Background to the study

Also known as the technology of the very small, nanotechnology is now regarded globally as the technology of the 21st century. Drexler (1988: 1) defines Nanotechnology as the "complete control of the structure of matter, building complex objects with molecular precision". Uddin and Chowdhury (2001: 1) also define Nanotechnology as "involving the manipulation and controlling of individual atoms and molecules to designing and creating new materials, nano-machines, and nano devices for application in all aspects of our lives. This technology is truly interdisciplinary in that it requires a joint effort between the disciplines of physics, chemistry, biology, medicine, chemical, electrical and mechanical engineering as well as material science (Uddin & Chowdhury 2001).

An important aspect of nanotechnology is that it has many applications ranging from computer, information, biotechnology, electronic, aerospace defence, manufacturing, environment, medicine and so forth. In the case of Medicine, Mehta (2003:2) reports that nanotechnology is expected to improve surgery and drug delivery by miniaturizing probes that can enter the human body and perform tasks like destroying cancerous tumours. There have already been notable achievements. Hunt (2003:3) reports that Scientists have already created a tiny vehicle that can cross from the blood into the brain to deliver tumour-destroying chemicals efficiently. Hunt (2003) claims that for instance, researchers in the United States of America have already developed Nanoshells, tiny beads of glass coated in gold that kill cancer cells when an attached capsule of poison bursts. In biotechnology, Mehta (2003) also reports that nanotechnology may be used to create novel organisms through the manipulation of DNA. In Aerospace engineering, space travel may benefit from nano-based coatings on spacecraft that have improved heat-shielding properties (Mehta: 2003). In Information Technology and

Communications, Mehta (2003) claims that for instance, desktop computers could one day be replaced by computers the size of postage stamps. Hunt (2003) reports that with nanotechnology, batteries will last for a very long time. He also reports that IBM is already producing nanoscale layers on disk drives for higher density data storage.

Singer et al (2005: 58) discuss the benefits of Nanotechnology to developing countries. The benefits include: agricultural productivity enhancement, energy storage production, and conversion, water treatment and remediation and improved drug delivery systems. In the case of agricultural productivity enhancement, Singer et al (2005) claim that Nanotechnology can help to develop a range of inexpensive applications (such as Zeolite nanoparticles) to increase soil fertility and crop production and this according to them will help to eliminate malnutrition, a contributor to more than half the deaths of children under five in developing countries.

For energy storage, production, and conversion, Singer et al. (2005) points out that Nanotechnology has the potential to provide cleaner, more affordable, more efficient, and more reliable ways to harness renewable resources. They claim that the use of nanotechnology can help developing countries to move toward energy self-sufficiency, while at the same time reducing dependence on non-renewable, contaminating energy sources such as fossil fuels. Since most developing countries have abundance of sunlight, they explain, solar energy is an obvious source to consider. Solar cells convert light into electric energy, and the current materials and technology for these cells are expensive and inefficient in making this conversion. Nanostructured such as quantum dots and carbon nanotubes are being used for new generation of more efficient and inexpensive solar cells.

In the case of water treatment and remediation, Singer et al (2005) indicate that one third of the population of rural areas in developing countries lack access to safe water supplies and as a result two million children die each year from water-borne diseases, such as cholera, typhoid, and schistosomiasis. They claim that Nanotechnology can provide inexpensive, portable, and easily cleaned systems that purify, detoxify, and desalinate

water more efficiently than do conventional bacterial and viral filters. These Nanotechnology-based water purification systems according to Singer et al (2005) include: nanofilter systems, nano porous zeolites and nanomagnets or magnetic nanoparticles. Nanofilter systems consist of intelligent membranes that can be designed to filter out bacteria, viruses, and great majority of water contaminants. Nano porous zeoites, which can bind large numbers of bacteria, can be used for water purification. Nanomagnets, when coated with different compounds that have a selective affinity for diverse contaminating substances, can be used to remove pollutants from water.

Singer et al also claim that nanotechnology can lead to improved drug delivery systems, reduce child mortality, improve maternal health, and combat AIDS, malaria and other diseases. Nanotechnology also promises more for less, that is, it involves smaller, stronger, cheaper, faster devices with greater functionality and efficiency, using fewer raw materials and consuming less energy. In fact, every sector of a country's economy is to be profoundly impacted upon by nanotechnology. (Singer et al., 2005; Hunt, 2003; Mehta, 2003; Drexler, 1998; Uddin & Chowdhury, 2001, Meyyappan, 2004; Fonash, 2001; Roco et al., 1999, 2001; 2002; Hung & Chu, 2004; Hassan, 2005; Glenn, 2005).

Nanotechnology has been on the political, scientific and educational agenda of many countries throughout the globe. Several initiatives in the United States of America, United Kingdom, Germany, France, Switzerland, Belgium, Netherlands, Ireland, Italy, Australia, Denmark, Austria, Finland, Sweden, Norway, Hong Kong, Canada, Japan, South Korea, China, India, Brazil, Malaysia, Singapore, the Philippines, Taiwan, South Africa, etc., highlight the international interest in nanotechnology. The government and private sectors in these countries have taken initiatives to accelerate funding for research and human resource development in nanotechnology. For instance, in the United States, Roco (2003) reports that the USA government and numerous private funding agencies, such as companies in chemical, computer and other areas, have increased their funding for research in support of nanotechnology.

Siegel et al. (1998) in Roco (2003) claims that the USA government agencies support for basic research in nanotechnology is estimated at about $116 million in 1997. Waters (2003) points out that the government of the United Kingdom has injected $144 million for Nanotechnology Research and Development and commercialisation over a six year period (2003-2008), $80 million for an applied research programme supporting collaboration between industry and the science base and $64 million for new and existing facilities making up the MicroNano Technology network. Waters (2003) also reports that Japan has a fully coordinated initiative for nanotechnology funding. According to him, the government spending in 2003 amounted to about $800 million. Furthermore, he reports that most Japanese largest companies such as Hitachi, Sony and Mitsubishi have spent an estimated $830 million in 2002 on Nanotechnology Research and Development.

In Taiwan, Waters (2003) says the government of Taiwan in 2002 launched a six-year $667 million investment to promote nanotechnology. Taiwan's nanotechnology programme is focused on commercialisation of applications, with 62% of funding directed to this end whilst the remainder to be used for basic academic research and development, setting up of research facilities and training/educational programmes. Waters (2003) also reports that the Chinese government support for nanotechnology amounts to $240 million in the next five years (2003-2007). A proportion of this funding will be used in setting up f a National Nanotechnology Centre and a supporting network of other Nanotechnology Centres. Smaller and poorer developing countries such as Thailand and the Philippines are also devoting a portion of their small science and technology budgets to nanoscience and nanotechnology (Hassan, 2005).

In Sub-Saharan Africa, with the exception of South Africa, the response to nanotechnology is still very slow. As cited in Hassan (2005: 3), Turner T. Isoun (2005), Nigeria's Federal Minister of Science and Technology noted that:

> Developing countries will not catch up with developed countries by investing in existing technologies alone. In order to compete successfully in global science today, a portion of the science and technology budget of every country must focus on cutting edge science and technologies

In light of the huge international research and development spending in nanotechnology, the South African government has already devoted part of its budget to research and human resource capacity development in nanotechnology.

1.2 Research problem

Upon seeing the long term potential benefits of Nanotechnology, the South African government approved the South African National Nanotechnology Strategy in December 2005. This strategy is aimed to ensure that South Africa is ready to optimally use Nanotechnology to enhance its global competitiveness and the quality of life of its people. The need for multi-institutional and multidisciplinary partnership in advancing nanotechnology has been a concern since the establishment of the National Nanotechnology Strategy. Consequently, an increasing number of South African Universities, such as the University of Kwazulu-Natal, the University of the North, the University of Pretoria, the University of Cape Town, University of Port Elizabeth, the University of the Witwatersrand, etc., have deepened their investigation into the area of Nanotechnology. Some of these universities have already established research cooperation with industries. Building on the assumption that research and development partnerships between the university and other economic sectors could enhance its role in the field of nanotechnology, this study looks at the role that the University of Witwatersrand has played in this field as well as whether it is aggressively seeking partnership and alliance with other knowledge producers. The study addresses the following main question: What is the role of the University of the Witwatersrand in the field of nanotechnology?

In doing so, the study pursues the following sub-questions: What is the general conception of Nanotechnology within the university? What has been the role of the university in the field of Nanotechnology? How does the role of the university match the South African Nanotechnology National Strategy?

The first question seeks to find out the emerging approach to nanotechnology within the University of Witwatersrand. It deals with issues such as whether research and teaching in nanotechnology at Wits is emerging within the narrow science and engineering boundaries or as an interdisciplinary domain and the possible implications of this. The second question focuses on the role the University of Witwatersrand plays in the field of nanotechnology. It examines the kind of training and research opportunities provided by Wits in the area of nanotechnology. It also looks at whether the University is working in partnership with other knowledge producers in developing human resource and research capacity in the area of nanotechnology. The third question examines whether the role Wits plays in the field of nanotechnology is in line with the South Africa National Nanotechnology Strategy.

1.3 Rationale

Research study on the role of University partnership in the field of Nanotechnology in South African Universities is almost non-existent. The few studies available focus on the traditional mission of the university in teaching, learning and research. This study seeks to extend the debate by introducing *the concept of partnership or inter-institutional collaboration* in research and training in the field of nanotechnology. In this regard, the study highlights how the changing context of knowledge production under globalization demands innovative strategies such as collaborative engagement of the university to safeguard or enhance its effectiveness and competitiveness in the field.

1.4. The argument

Globalisation has significantly changed the pattern of knowledge production in higher education institutions. As a result there is a tendency towards supplementing knowledge produced within single discipline with knowledge produced in the context of application. Focusing on South Africa, the study argues that the teaching and research role of the University of Witwatersrand in the area of nanotechnology can be enhanced through partnership with knowledge practitioners located in multiple knowledge generating sites

and institutions such as government, other universities, industries, research councils and civil society. As Subotzky (1999: 404) has pointed out

> The production of new knowledge is increasingly occurring within new forms of social organisation. High-tech research is being conducted in collaborative business, government and university-linked consortia, specially established to meet the short-term needs of specific clients or problems. As higher education is a key player within this new knowledge, these new formation and processes have understandingly had a profound effect on the organisation of higher education research and graduate training in relevant fields.

Besides new opportunities in research and development, partnerships or inter-institutional collaboration has also the effect of integrating primary or Mode I forms of knowledge production with Mode II forms, that is, it emphasises the production of knowledge in the context of application. This is what makes it possible for different kinds of knowledge producers such as physicists, chemists, biologists, electrical engineers, mechanical engineers, chemical engineers, material scientists, government, business and civil society etc, to "develop dialogical partnership through which they become jointly responsible for effectiveness of student learning, curriculum development and research development". (Waghid, 1999: 471).

In this regard, Wits University is collaborating with academic and research institutions in the country such as Vaal University of Technology, CSIR, MINTEK, University of Pretoria. It also collaborates in teaching Nanotechnology with NASA, USA, and in research with the National University of Malaysia, also known as the Universiti Kebangsaan Malaysia (UKM) in the filed of Proton Exchange Membrane Fuel Cell (PEMFC), to mention a few.

1.5 **Outline of chapter**

This study comprises seven chapters.

Chapter one - Introduction - introduces the study, by providing a background to the study, outlining the research problem, aim, rationale and the central argument as well as a brief outline of chapters.

Chapter two - Literature review - provides a review of related literature about the study as well as a theoretical framework used to analyse the research data. Emerging from the literature is the argument that globalisation and the need for new technology have led to a new way of producing knowledge. The traditional ways of producing knowledge within single disciplines and institutions are being supplemented by knowledge produced within various applied contexts. The main issues explored in the chapter are: globalisation and the changing role of the university, the entrepreneurial university, the new mode of knowledge production, university-industrial partnership: implication for nanotechnology, university and government collaboration, the mode of research and training in nanotechnology and theoretical framework.

Chapter three - Research methodology - discusses the research methods and the design used in the study, and provides rationale for choosing the methods. It also explains the selection of the sample and issues such the question of anonymity and confidentiality of the respondents. . The chapter also deals with the reliability and validity as well as the limitation of the study. Discussion on how the data was analyzed, by using thematic analysis is also presented in the chapter.

Chapter four - Contextual issues - provides the context in which to understand nanotechnology activities at Wits. The main argument pursued in this chapter is that the interplay of global and national pressures has led to the need for partnership and application based approach to nanotechnology in higher education institutions. The following issues are discussed in the chapter: globalisation pressure on higher education system, government and nanotechnology in South Africa, higher education institutions and industries.

Chapter five - The South African National Nanotechnology Strategy - focuses on the development and the implementation of the South African Nanotechnology Strategy. The chapter argues that the need for nanotechnology as a result of globalisation has put pressure on the government of South Africa to develop a National Nanotechnology Strategy. It explores the issues of the development and implementation of the strategy on nanotechnology in South Africa and the implication for the University of the Witwatersrand.

Chapter six - The role of the University of the Witwatersrand in the field of nanotechnology - examines the role of the University of Witwatersrand in the field of nanotechnology. The chapter claims that nanotechnology at Wit is more multidisciplinary in nature than interdisciplinary, with little interaction among faculties and other knowledge producers such as industries, research institutes, and other universities. The chapter further claims that for Wits to play more effective role in research and human resource capacity development in the area of nanotechnology, it has to work in partnership with other knowledge producers. such as government, industries, research institutes and other universities. This is because nanotechnology is not just multidisciplinary in nature but also interdisciplinary in nature, and so should not allow for monopoly of knowledge by a single institution.

Chapter seven: Conclusion and recommendations. Chapter seven is the conclusion of the study and provides recommendations for further study.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Introduction

This chapter provides a review of selected literature on the role of university partnership especially in the area of nanotechnology. The chapter argues that globalisation and need for new technology such as nanotechnology have led to a new way of producing knowledge in the context of higher education institutions with considerable implications for the field of nanotechnology research and training. The traditional ways of producing knowledge within single disciplines and institutions are being supplemented by knowledge produced within various applied contexts. The chapter explores the following issues: (i) globalisation and the changing role of the university; (ii) the entrepreneurial university; (iii) new modes of knowledge production; (iv) university-Industrial partnership; (v) university and government collaboration; and (vi) modes of research and training in nanotechnology. More specifically it explores the implications of these issues for the field of nanotechnology. The chapter closes with a theoretical Framework that has informed this study.

2.2 Globalisation and the changing role of the university

Globalisation according to Tickly (2001: 152), lacks a precise definition. However, Held et al. (1999) in Tickly (2001) attempt to define globalization as "a process or set of processes which embodies a transformation in the spatial organisational of social relations and transaction – assessed in impact-generating transcontinental or interregional flows and networks of activity, interaction, and the exercise of power. According to Held and colleagues, "flows refer to the movements of physical artefacts, people, symbols, tokens and information across space and time, whilst 'networks' is used to refer to regularised or patterned interactions between independent agents, nodes of activity or sites of power. Similarly, Subotzky (1999: 404) defines globalisation as the "process of

intensified transnational economic and social relations leading to complex-economic changes, which has had a profound impact on both business and higher education. Tunnermann-Bernheim and Chaui (2000) argue that the definition of globalisation is not confined purely to economic aspects; it is in fact a multidimensional process taking in aspects relating to the economy, finance, science and technology, communications, education, culture and politics. According to them, globalisation is inescapable.

Globalisation and the changing role of the university have been well documented. (Gibbons et al., 1994; Gibbons, 1997; Kraak, 1995; Schuler, 1995; Carnoy, 1998; Walshock, 1996; Slaughter and Leslie 1997, Currie and Vidovich 1998; Polster and Newson 1998; Subotzky, 1999; Gumport, 2000; Clark, 1998; Pearson, 1985; Maasen and Cloete, 2002) Contributing to the debate on the changing role of the university in the context of globalisation, Gumport (2000: 17) in Maasen and Cloete (2002) argues that there is a growing tension between two dominant perspectives on higher education. The first views higher education as a social institution while the second perceives higher education mainly as a part of national economy, in other words, as an industry. Gumport (2000) reports that the social institution position states that higher education must attain goals related to its core activities, retain institutional legacies and carry out important functions for the wider society such as the cultivation of citizenship, the reservation of cultural heritage and the formation of skills and the character of students. The higher education as an 'industry" approach on the other hand emphasises that higher education institutions sell goods and services, train an important part of the workforce and foster economic development. It argues that the exposure of universities and colleges to globalisation and competition will result in improved management, programmatic adaptation, maximum flexibility, improved efficiency, and customer satisfaction.

Subotzky (1999) claims that the current developments in information technology and the need for flexibility and innovative responsiveness to rapidly market conditions have significantly changed the pattern of production, research and development. He also argues that the impact of globalisation on higher education institutions is "characterised by three levels of marketization: epistemological and organisational changes towards

applications-driven or strategic forms of knowledge production and dissemination; and through this, greater responsiveness to societal needs, with the dominant emphasis on meeting the interests of the private sector market, and changes in institutional management style towards managerialism and entrepreneurial income generation". The next section discusses in detail the globalisation discourse of the mode of an entrepreneurial university and its implication for nanotechnology.

2.3 **The entrepreneurial university**

Several scholars have contributed to the discussion of the emergence of the entrepreneurial university brought about by globalisation (Clark, 1998; Subotzky, 1999; Dill 1997; Orr 1997; Slaughter and Leslie, 1997; Tierney, 1997; Maasen and Cloete, 2002; Jongbloed and Geoedgebuure, 2001). Traditionally, universities have been autonomous and independent institutions from the market and the state. However, global conditions have led to a strong trend towards the entrepreneurial university. This has changed not only the epistemological and organisational forms of knowledge production and dissemination, but also the role of the state in relation to higher education (Orr, 1997) in Subotzky (1999).

Maasen and Cloete (2002) point out that for higher education institutions to be able to respond successfully to the challenges posed by globalisation, they should become more business like and produce more graduates with high-level knowledge of skill. Similarly, Clark (1998) argues that all universities should adapt and become more entrepreneurial because societal demands with respect to higher education are growing while governmental support (financially, legally and politically) is decreasing. According to Clark,

> An entrepreneurial university, on its own, actively seeks to innovate in how it goes about its business. It seeks to work out a substantial shift in organisational character so as to arrive at a more promising posture for the future. Entrepreneurial universities seek to become "stand-up" universities that are significant actors on their own terms. Institutional entrepreneurship can be seen as both process and outcome, which should include all activities connected to teaching, learning, and

> exploitation of research results. It also implies the promotion of the university as organisation, as well as producer and ambassador of new technologies (Clark, 1998: 4).

Clark (1998) also discusses five elements that constitute entrepreneurial universities. Firstly, entrepreneurial universities according to Clark exhibit a strong capacity to steer themselves. Accordingly to him, these universities need to become quicker, more flexible, and especially focussed in reactions to expanding and changing demands. Secondly, he argues that universities exhibit growth of units more readily than traditional academic departments, and reach across old university boundaries to link up with outside organisation and groups. These units include professionalized outreach offices that work on knowledge transfer, industrial contact, intellectual property development, continuing education, fundraising and even alumni affairs.

Thirdly, he states that entrepreneurial universities need discretionary funds. They need to increase their financial base since they do not get much support from government. They should step up their efforts by raising money from other sources, such as royalty income from intellectual property, research councils, industrial firms, etc. Fourthly, he points out that for change to take place, one department and faculty after another needs itself to become an entrepreneurial unit, reaching more strongly to the outside with new programs and relationships and promoting third-stream income. In the entrepreneurial university, the heartland accepts a modified belief system. Their members need to participate in central steering groups. They need to accept that individuals, as well as collegial groups, will have stronger authority in a managerial line that stretches from central officials to heads of departments and research centres. Finally, he also points out that enterprising universities must develop a work culture that embraces changes. The new culture may start out as a relatively simple institutional idea about change that later becomes elaborate into a set of beliefs, and if diffused in the heartland, becomes a university wide culture. In order to secure a place in the global economy, universities are also forced to carefully reconsider their role. For instance, Slaughter and Leslie (1997) argue that the impact of globalisation on higher education has resulted in university management encouraging entrepreneurial activities among faculty. Most countries are now moving away from

basic research and heading towards more academic capitalism such as consulting, business partnership and commercialisation of research results and intellectual property.

Similarly, Subotzky (1999) claims that, "some universities have appointed new kinds of "knowledge workers" – entrepreneurial scientists. University academics increasingly have to assume entrepreneurial and fund-raising roles. Academics across the board are now faced with developing skills in interdisciplinary and team project management and networking. Subotzky (1999) also points out that in industrialised countries, globalisation has shaped "research and teaching priorities towards the commercialisable science and technological fields and away from the social sciences, humanities and education". Subotzky (1999) argues that globalisation pressure is seen to be changing academic epistemology. Faculty engaged in academic capitalism are reconceptualising knowledge in such a way to value entrepreneurial research more highly, especially that on the leading edge of science and technology and innovation. According to Subotzky (1999: 413) the implication of an entrepreneurial university includes changes in the form, focus and dissemination of knowledge involving: the commodification of knowledge and the shift towards "mode 2" knowledge; research increasingly funded by non-statutory, private commissioned sources; new forms of quality and evaluations, including indicators; the emphasis on science and technology fields rather than non- commercial stable research; technology transfer through business-university research partnerships, consortia and specialist units, leading to proprietary intellectual rights and the fragmentation of teaching and research .

The implication of Entrepreneurial University for Nanotechnology is that it will open more opportunities for the development of research and training in higher education institution both globally and in South Africa. This will see the universities, not only involving in traditional teaching and research but encouraging nanotechnology entrepreneurial activities among their faculties members such as : "developing income-generating products and marketable services, consulting, business linkages, interdisciplinary partnerships and knowledge production in ongoing enterprises and producing income from technology transfer activities which provide intellectual

property" (Slaughter and Leslie, 1997) in Subotzky (1999: 414). The technology transfer activities in nanotechnology thus include all activities connected to nanotechnology teaching, learning and exploitation of results of basic and applied research to the design, development, production and commercialisation of new and improved products and services.

2.4. The new mode of knowledge production

According to Gibbons et al. (1994), a new mode of knowledge has emerged which is distinct from traditional notions of knowledge generation. It is refereed to as Mode 2, and contrasted with the traditional Mode 1 knowledge production. According to Gibbons et al "Mode 1 refers to a form of knowledge production in which problems are set and solved in a context governed by the, largely academic, interests of a specific community. By contrast, Mode 2 knowledge production is carried out in a context of application. It includes a wider, more temporary and heterogeneous set of practitioners, collaborating on a problem defined in a specific and localised context". Gibbons et al. (1994) argue that higher education is experiencing a fundamental shift from what they call "Mode 1" to "Mode 2" forms of knowledge production. In their thesis they highlight the relevance of higher education in the 21st century in terms of the need to adapt and respond to new modes of knowledge production. They argue that universities are presently organized in accordance with the structures of disciplinary science, which they term "Model 1". They refer to the emerging new mode of knowledge production as "Mode 2", that is, knowledge which is produced in the context of application.

Yarzabal (1999) in Tunnermann-Bernheim & Chaui (2003) claims that knowledge from being single-discipline, has become interdisiciplinary. It is problem-centred and not discipline-based; it is produced in various areas closer to its application and has shifted from academic circles to draw nearer to entrepreneurial and industrial production fields. Similarly, Delanty (2001) claims that one of the major implications of the new knowledge production theory is that the university will no longer dominate the field of knowledge production as it did for much of the modern age, and accordingly will go into

decline. The features which distinguishes mode 2 from mode 1 is discussed in more detailed in terms of the following: knowledge in the context of application, transdisciplinarity, heterogeneity, social accountability and quality control.

Transdiciplinarity and knowledge in the context of application

In Mode 2, knowledge is produced in context of application, unlike the traditional university mode where a problem is performed within a disciplinary context. In mode 2, knowledge is shaped by a large number of different actors (academics, government, business, students, parents, communities and other groups) negotiating the problem to be solved (Gibbon et al. 1994). The second attribute that distinguishes "Mode 2" from "Mode 1" is its transdisciplinarity. Gibbon et al. (1994) view "Mode 1" as mainly disciplinary and "Mode 2" as transdisciplinary, that is, transcending the boundaries between disciplines. According to them, "Mode 2" transdisciplinary knowledge

> consists in a continuous linking and re-linking, in specific clusterings and configurations of knowledge which is brought together on a temporary basis in specific contexts of application. Thus it is strongly oriented towards and driven by problem solving. Its theoretical methodological core, while cross-cutting through well-established disciplinary cores, is often locally driven and locally instituted, thus, any such core is highly sensitive to further local mutations depending on the context of application.

Heterogeneity and organizational diversity

Another feature of the Mode 2 knowledge production is what Gibbons et al. (1994) call knowledge that is heterogeneous and organizationally diverse. This mode of knowledge production brings together teams of knowledge producers with diverse backgrounds such as academics, production engineers, industries, social scientists, researchers, consultancies and civil society organizations. Unlike Mode 1 which is homogenous and deeply institutionalised, with limited multi-agency collaboration. In Mode 2 according to Gibbons et al. (1994),

> Teams of knowledge producers dissolve when a problem is solved or redefined. Members may then reassemble in different groups involving different people, often in different loci, around different problems. Though problems may be transient and groups short-lived, the organization and communication patterns persists a matrix from which further groups and networks, dedicated to different problems, will be formed.

Social accountability and reflexivity

This Mode 2 knowledge is produced by involving people critically and reflexively in action for the reason that the issue on which research is based cannot be answered in scientific and technical terms alone (Gibbons et al. 1994). Their view supports Giroux's (1992) in Waghid (2002: 468):

> Teams of diverse workers constitute a collaborative group of critical inquiry that links the need for greater social accountability to the acknowledgment of other viewpoints. They are different, yet they inter-subjectively share and negotiate patterns of meaning in order to broaden the conditions for the production of socially relevant knowledge. They become more reflexive and sensitive to the broad social implications of their work in varying contexts. In this way, people are self-critical, yet remain socially engaged, that is, in "constant dialogue" with others (educators, researchers, planners, community groups, and so on) and other viewpoints to address the most pressing social (educational) and political problems of their time.

Quality control

In Mode 2 the main criterion for judging the quality of knowledge produced is not just peer review as practiced in traditional Mode 1 university. Additional players whether from university, research councils, government departments or industry, bring "external criteria" to review process" (Waghid, 2002: 468). In judging the quality of knowledge produced, Gibbons et al. (1994) based their argument on the following:

> So, the peer review process is one in which quality and control mutually reinforce one another. It has both cognitive and social dimensions, in that there is professional control over what problems and techniques are deemed important to work on problems judged be central to the advance of the discipline. These problems are defined largely in terms of criteria which reflect the intellectual interests and preoccupations of the discipline and its gatekeepers… (In "Mode 2") since it is no longer limited strictly to the judgment of disciplinary peers, the fear is that control will be weaker and the result in lower quality work. Although the quality control process in Mode 2 is more broadly based, it does not follow that because a wider range of expertise is brought to bear on a problem it will necessarily be of lower quality. It is of a more composite, multidimensional kind.

Gibbon et al (1994) however view Mode 1 and Mode research operating in parallel, with the new mode of knowledge production supplementing rather than replacing traditional Mode 1 knowledge production. They suggested that:

> Although Mode 1 and Mode 2 are distinct modes of production, they interact with one another. Specialists trained in the disciplinary sciences do enter Mode 2 knowledge production. While some may return to their original disciplinary based others will choose to follow a trail of complex solving [of] problems that are set by a sequence of application contexts. Conversely, some outputs of transdisciplinary knowledge production, particularly new instruments may enter into and fertilise any number of disciplinary science

Waghid (2002: 470) discusses 3 implications of the shift from Mode 1 to Mode 2 that have a bearing on the role of the university and have particular significance to this study. Firstly, according to him citing (Subotzky, 1999), the implication is that the shift from Mode 1 to Mode 2 knowledge of production, that is, knowledge produced in the context of application characterized by transdisciplinarity, heterogeneity, organizational diversity and increased social accountability and reflexivity accompanied by new forms of quality control, has the effect that universities in particular will have to adjust from being adept producers of mainly disciplinary knowledge to being creative reconfigurers of knowledge in solving increasing complex problems.

Secondly, Scott (1995) in Waghid (2002: 471), summarizes some of the challenges the shift to Mode 2 offers to higher education institutions as follows:

- Higher education institutions will no longer remain the supreme provider of both new knowledge and skills for the reason that they must compete with other public and private institutions.

- Socially distributed knowledge emerges as an important source of knowledge in accredited learning programmes and research as academics and the public come to disregard the institution between disciplinary academic knowledge and relevant knowledge.

- Programmes of learning will increasingly become modularized to ensure greater flexibility to society's diverse needs.

Thirdly, the Mode 2 knowledge production makes it possible for different kinds of knowledge such as scientific, technological and industrial to coexist as well as to increase the level of co-operation between people located at different institutions. For instance, research scientists, business people, patent lawyers, production engineers, etc, develop dialogical partnerships through which they become jointly responsible for effectiveness of student learning, curriculum development, and research community development. (Waghid, 2002: 471).

Similarly, the implication of the changing mode of production of knowledge for nanotechnology is that the conduct of research and training in the domain of nanotechnology will not remain within the confines of the universities. Given the nature of the new mode of knowledge production, universities which intends to remain forefront in research and training in nanotechnology will now have to organize themselves to "become more open, porous institutions, more aggressive in seeking partnership and alliance they are currently" (Gibbons, 1998: 10). This means that university academics

will not only interact with their academic colleague but also interact with knowledge producers in a range of other institutions such as government, research councils, civil society, industries etc, both locally and internationally to provide human resource and research capacity in the area of nanotechnology

2.5 University-industry partnership

The university- industry partnership has been a subject of increasing attention in recent years. The rapid growth of globalisation and the increased pressure exerted on universities from many sources have resulted in universities seeking partnerships with the private sector, not only as a source of funding, but also for a broader relationship. The University-Industry relationship is seen as a key factor in ensuring economic growth and better quality of living for the society. (Slaughter and Leslie, 1997; Jongbloed & Goedegebuure, 2001, Gibbon et al., 1994; Clark , 1998).

Various scholars have discussed the issues of university and industrial partnership, especially in the area of nanotechnology. Harayama (2000) in his study on "Technological paradigm change and the role of the university research", reports that academics interviewed in his study claim that besides the traditional role of the university to contribute to the advancement of science and technology, that there are some other roles to which the university should attach great importance. For instance, instead of being isolated from the industry under the pretext of maintaining some autonomy, the university should be a credible partner to industry and should help industry solve the problem it faces. In other words, the scholars perceive complementarity between university and industry.

Harayama (2000) in his study reports that one of the university professors interviewed emphasized that instead of following the traditional linear model, the contribution of the university to technological advancement per se is greater by first helping industry develop new products and then subsequently deepening the underlying scientific base, which may change during the process. He also affirms that the social contribution of the

universities in the ever growing technological field would be much greater if they transfer their knowledge in the form of a product rather than just licensing the property right.

Martinez-Fernandez and Leever (2000) argument is in line with the claims presented in Harayama's (2000) study. They argue that successful transfer of knowledge from university to industry in the area of nanotechnology could stimulate adoption of new knowledge in firms and new learning could be established contributing to the critical long-term capacity for growth of new enterprises. Among these critical capacities according to them, are the commercialisation know-how, reaching finance providers and increasing Intellectual Property(IP) value in practical terms, both specialised public sector researchers and companies generate new knowledge, refine and add to existing technological know-how. They say however, that if public sector research is to be maximally effective, researchers need to be more actively interact with user organisations. This interaction according to them, needs to be oriented not only to present needs but specially to the exploitation of future opportunities where public sector research might tackle resources on technology complementary assets. They call for universities and industry to be more active in collaborating and transferring knowledge. Martinez-Fernandez and Leevers (2004), however, claim that universities and industries sometimes find it hard to match their interests because universities undertake basic research while industries largely invest in experimental developmental, an activity much more closely related to their immediate commercial needs. Subotzky (1999) has argued that collaboration with industry should not disrupt the traditional disciplinary based organisational features and function of higher education, but rather promote and strengthen it.

Literature has also shown examples of University-Industry partnerships. For instance, Harayama (2000), reports that private companies in Japan enter into contracts with Japanese universities in the area of nanotechnology through joint research, grants or endowments. According to him, joint research has several induced effects besides and beyond the expected transfer of knowledge. In the framework of joint research, the contracting company sends its researchers or engineers to its counterpart university to

realise the research project. These researchers from private companies consider the university's laboratory as a privileged place to do brainstorming, to discuss and get advice on their problems, and to learn the nature of the technique involved. Through these researchers, embodied knowledge crosses from the universities to private companies.

Another example of University-Industry relationship according to Harayama (2000) is that of knowledge transfer from industry to University. For instance Harayama reports that in Japan private companies are sometime invited to give lectures at the Japan universities. This practice according to him provides students with the chance of becoming aware of those problems facing the real world of production and whilst for the people in the industry, it may be seen as a means of enlarging or consolidating their personal network.

The website of the Massachusetts Institute of Technology (MIT), in the United States of America also provides the following examples of University-Industry partnership:

> In March1994, MIT and Amgen, a leader in biotechnology, entered into a long term research collaboration to pursue joint research initiatives. Engaging the biological science community at MIT, the research relationship was established principally with the Departments of Biology and of Brain and Cognitive Sciences, including the involvement of MIT professors working at the Whitehead Instituted. With total support of about $30 million for a projected 10-year period, this was the first large-scale alliance between MIT and Industry. The Amgen/MIT strategic partnership is a model of a mutually rewarding relationship bringing benefit to both organizations and recognizing the distinctive role of each.
>
> In October 1996, Microsoft and MIT announced an alliance to enhance university education through information technology. Named "Project I-Campus," the collaboration will involve cooperative project among students, faculty and researchers at MIT and members of Microsoft Research. In addition to assigning several research staff members to this effort, Microsoft is allocating $25 million for work at MIT over the project's five-year lifetime. Both MIT and Microsoft plan to engage additional academic and industry partners and produce materials that can be widely published

> and disseminated. Through and initial focus on methods and technologies that will enhance education on the MIT campus, it is expected that Project I-Campus could set the pace for university education in the next five to 10 years.
>
> In September 1999, DuPont and MIT announced they had agreed to form a 35 million alliance. The goal of this alliance is to advance research and education in materials from biotechnology that has a variety of applications. Beginning Jan. 1, 2000, the five-year alliance will support projects that draw upon the science, engineering and business expertise at MIT and that extend and better leverage the reach of DuPont's scientific expertise in the area s of biology, genetics, bioinformatics and catalysis. It will bring together DuPont's and MIT's strengths in materials, chemical and biological sciences to develop processes for new materials directed at bioelectronics, biosensors, biomimetic materials, alternative energy sources and new high-value materials. Through the alliance, DuPont also will work with MIT's Sloan School of Management to define new business models for these emerging technologies.
> (http://web.mit.edu/newsoffice/nr/2000/alliance.html)

In the case of the universities in South Africa, partnerships between University and Industry in the area of nanotechnology are not very developed. There have been only few cases of University –Industry linkages. This is blamed on the "fragmented nature of the South African research landscape, the multidisciplinary nature of Nanotechnology, and the patchiness of mechanisms to facilitate the transfer of technology to industry". (South African Nanotechnology Strategy, 2003). At present, there is an ongoing research collaboration between few companies such as (SASOL, ESKOM, Element Six, PPM, Anglo Platinum) with Universities such as the University of Cape Town, Pretoria, Port Elizabeth, Kwazulu Natal, Western Cape, Wits etc. University of Western Cape for instance is engaged with a project with ESKOM on water treatment technology using nanoscale fitration membranes.

2.6. University and government collaboration

The powerful forces driving change in our world today, such as globalisation and new technology are demanding a change in the role and relationship between government and higher education institutions. This is true in the domain of nanotechnology where there has been an increasing call for government and university collaboration. In Europe, USA, Asia, Australia, Canada, South Africa etc, government has developed national nanotechnology strategy to provide "leadership in the pursuit of knowledge in the fundamental academic disciplines through conduct of more applied-mission and product-focused research that addresses national priorities such as health care, environmental sustainability, economic competitiveness, national defence, information technology etc. (Duderstadt, 2005).

Hersam et al. (2004) report that in the United States of America, the federal government support for nanotechnology was channelled through an array of government funding agencies such as the National Science Foundation, the National Institutes of Health, the Department of Defense, and the Department of Energy to pursue Nanotechnology related research and education to help satisfy the economic, health, national security and energy need of the country.. Roco (2002) also reports that the USA government, through the National Science Foundation provide research grant to universities to conduct basic research in the University, along with contract to industrial research and development laboratories for more applied research and development aimed at meeting the specific needs of the country.

The USA government believes that a well-educated, skilled force and a supporting infrastructure of equipment and facilities are essential foundation of its Nanotechnology initiatives (Roco, 2002). Based on this, Roco (2002) points out that the USA government has therefore built a substantial education program focused on nanosceince and nanotechnology not only for K-12 and vocational students but also for the universities. They include providing hands-on training of undergraduate, graduates students, and post doctoral researchers at universities, Federal laboratories and other research institution..

Through participating agencies, the government has also awarded funding directly to students for fellowships and traineeships that give recipients flexibility in choosing areas of research, especially those that cross multiple disciplines. The on going efforts in infrastructure include, the establishment and maintenance of geographically distributed infrastructure that provides access to advanced instrumentation for fabrication, characterization, modelling and simulation of nanoscale and nanostructured materials, devices and systems for researchers from university, industry and government.

The government also recognises the importance of nanotechnology research to long term product development and profitability. For this reason, Duderstadt (2005) reports that additional federal polices were developed to strengthen further this partnership among universities, industry and the federal government such as the Bayh-Dole Act, which gave universities ownership in the intellectual property developed through federally sponsored research, thereby stimulating the transfer of knowledge from the universities to the market place.

Another good example of university and government collaboration in the area of nanotechnology is seen in the case of Australia. The Australia government has also provided extensive support to universities to develop human resource and research capacity in the area of nanotechnology. At the State level, the Queensland government is establishing the A$60 million Australian Institute of Bioengineering and Nanotechnology (AIBN) at the University of Queensland (The Australian Department of Communication, Information Technology and the Arts, 2005). The Nanomaterials group at Flinder University in Australia, also received a A$1.2 million Australian Government International Science Linkages grant for sol-gel nanotechnology research, the larges grant awarded to dated under this scheme, for the investigation of so-gel nano-composites.

The South African National nanotechnology strategy emphasizes the issue of developing human resource capacity, building research and development capacity, provision of infrastructure and the issue of norm and standards. In terms of capacity building, the government is concerned with the need for highly trained, skilled and innovative

workforce in the field of nanotechnology. For this reason, the government has established a dedicated fund for the support of the implementation of multidisciplinary, interdisciplinary and inter-institutional postgraduate nanotechnology programme in the university to prepare students for the emerging field of nanotechnology (The Department of Science and Technology, 2005).

In the case of building research and development capacity, the government, through its various agencies such as National Research Fund and the Department of Science and Technology, have provided not only fund to academics researchers but to final year undergraduate and postgraduate bursaries and other incentives dedicated to Nanotechnology Research and Development. The government investment in research and development in nanotechnology especially encourages a closer collaboration between the Universities and Industries. With reference to infrastructure, the government is establishing multi-user facilities that will provide nanotechnology researchers in the universities with advanced instruments for design, synthesis, characterisation, modelling and fabrication. The issue of norms and standards is very important to the concept of nanotechnology in higher education institutions as a way of making sure there is equal access of education and training opportunities in the area of nanotechnology. As a result the government has ensured that Nanotechnology in South Africa will create opportunities for human capacity development for historically disadvantage individuals, institutions, women and people of disabilities. Furthermore, the government also gives South African Universities the opportunity to assume the rights to commercialised patentable invention made by academic in the area of nanotechnology (South African Nanotechnology Strategy, 2003).

2.7. Modes of research and training in nanotechnology

As regards the research and training functions of the Universities, there has been an increasing call for the development of research capacity and training of workforce for the emerging field of nanotechnology (Roco, 2002; Chang, 2002; Uddin and Chowdhury,

2001; Iyuke, 2006; Meyyappan, 2004; Hersam et. al. 2004). It is estimated that about 2 million workers will be need worldwide in 10-15 years from now (Roco, 2001).

With regards to the issues of the research function of the university in the area of nanotechnology, some universities in countries such as Australia, America, United Kingdom, Japan, India, South Africa are already involved in research activities. The current nanotechnology research at these universities reveals a particular pattern and degree of multidisciplinarity, interdisciplinarity, inter-institutional and intergeographic collaboration. According to Schummer (2004:444), a research field is multidisciplinary, if many disciplines are involved, such as Chemistry, Physic, Biology, Chemical Engineering, Mechanical Engineering, Electrical Engineering. Interdisciplinary is where researchers from at least two different disciplines, according to their departmental affiliation interact or are involved in research activities. Interinsitutional show collaboration between different institutions such as the university/industry collaboration. Intergeographic collaboration is collaboration between different countries such as USA/Japan (Schummer, 2004).

Nanotechnology research activities in Australia for instance, show some degree of multidisciplinarity, interdisciplinarity, inter-institutional and intergeographic collaboration. For instance, research in the Australian National University (ANU) is multidisciplinary in nature, that is, several faculties and schools such as Engineering and Science are involved in nanotechnology research activities. In terms of interdisciplinary collaboration, an interdisciplinary team such as those from Chemistry, Physics and Engineering at Institute for Nanoscale Technology at the University of Technology Sydney (UTS) is involved in nanotechnology research such as modelling of gold nanostructures, self-assembled monolayers on gold and experimental characterisation via a number of techniques of proposed structures. They are also developing self-assembling systems for making optically-active composite nanomaterials devices. In terms of inter-institutional collaboration, the Lan Wark Research Institute, at the University of South Australia is involved in research collaboration with Monash University, Sidney University and industries such as Mayne Pharma, Rio Tinto, Sola International, and

Schefenacker Vision Systems. They are involved in investigating nanotechnology applications across bio and polymer interfaces, colloids and nanostructures, minerals processing, materials and environmental surface science. In term of inter-geographical collaboration, The Australian National University (ANU) Research School of Physical Sciences and Engineering is involved on a variety of nanotechnology programmes with the United States of America, Europe and Japan. Area of research collaboration includes the creation of magnetic forms of carbon, by breaking bonds with its structure (The Australian Department of Communication, Information Technology and the Arts, 2005).

The mode of research in nanotechnology in South African universities is highly multidisciplinary, with few cases of interdisciplinary and inter-institutional collaboration. Different faculties such as Science, Health Science and Engineering are involved in nanotechnology research. This is the case in the Universities of Witwatersrand, Cape Town, Pretoria, Kwazulu Natal, etc. In the University of Cape Town, different faculties and schools are into nanotechnology research. For instance, the Department of Physic is researching into Solar Cell development using nanotechnology, the Department of Chemistry is involved in Nanophase catalysts, electrocatalysts applied in fuel cells, exhaust gas treatment, chemical production, and waste water treatment. . In terms of inter-institutional collaboration, the University of Cape Town is also involved in research collaboration with ESKOM in the area of water treatment technology using nanoscale filtration membranes or electro catalytic disinfections hyochlorite generation Unit. Similarly, different Faculties and schools in the University of the Witwatersrand (Wits) are also involved in nanotechnology research. These faculties include: Health Science, Engineering and Science. Interdisciplinary research collaboration is also evident in the case of Wit. For instance, the School of Chemistry is involved in research collaboration with SASOL, Jonson Mathey Technology Centre, UK, Mintek and Aglogold. (South African Nanotechnology Strategy, 2003).

With reference to the training function of the university in the domain of nanotechnology, Chang (2002: 486) supports the training of students in the broad knowledge based and crosscutting programs in the interdisciplinary field of nanotechnology, which, according

to him, will prepare students for the challenges presented by today's industry's dynamic environment. He calls for the transformation of the engineering curriculum starting from the undergraduate degree level to include nanotechnology education. Uddin and Chowdhury (2001), however, argue that higher education institutions are not providing enough educational opportunities for the emerging field of nanotechnology, as only a few Universities in the USA, Europe, Australia and Japan are currently offering selective undergraduate and postgraduate programs in nanoscience and nanotechnology in collaboration with research institute and industries. They suggest that in order to prepare students to solve the technological challenges of the new millennium, there is a need to provide nanotechnology education and training to students. For this purpose, they call for an interdisciplinary curriculum that encompasses a broad understanding of basic sciences intertwined with engineering sciences and information sciences. Nanotechnology according to them should be taught by creating both knowledge-centred and learning-centred environment both inside and outside the classroom. Furthermore, they suggest activities that encourage problem solving skill, critical thinking and life long learning. Similarly, Hersam et al (2004) argues for a shift from passive, principle-based learning to active, problem based learning in the area of nanotechnology.

The current mode of training in nanotechnology in higher institution in America, Australia, Japan etc is consistent with the interdisciplinary appeal of nanotechnology. For instance, in the United States of America, Meyyappan (2004:312) states that he offered a course known as "Introduction to Nanotechnology" at Santa Clara University (SCV). The course, according to him, drew students from Chemistry, Physics, Mechanical Engineering, Chemical Engineering and Electrical Engineering. Hersam et al (2004), in their work, describe their efforts to implement problem-based learning approach to an interdisciplinary nanotechnology engineering course at Northwestern University, USA. The Nanotechnology engineering course attempts to develop these skills through interdisciplinary student-centred group work.

In line with the interdisciplinary nature of nanotechnology, Hersam et al. (2004) states that the course attracted 8 undergraduate and 9 undergraduate students from a variety of

departments such as electrical engineering, mechanical engineering, material science and Chemistry. The course according to them was designed in such a way brings together a range of non-traditional pedagogical practices, including collaborative learning, problem-based learning, peer assessment and interdisciplinary approach to construct a learning environment in which students are not only exposed to the Scientific and engineering issues surrounding nanotechnology but are given the opportunity to develop interpersonal, critical evaluation skills that are necessary for effectively advancing nanotechnology. In Australia, Shapter et al. (2002) reports that Nanotechnology course at Flinders University was developed by a team of academics from the Faculty of Science and Engineering. This course according to them also drew students from a variety of disciplines such as chemistry, physics, biology, mathematics and engineering.

Iyuke (2006) reports that in South Africa, few local universities, such as the University of the Witwatersrand and the University of Kwazulu-Natal have started offering training courses in the field of nanotechnology. For instance, an introductory course and training was held at the School of Chemical and Metallurgical Engineering at the University of the Witwatersrand from 19-20 October 2005. This course drew participants from various countries and Institutions, such as those from the universities, industries and research institutes. Furthermore, a new course, known as Advanced Chemical Engineering: Carbon Nanotechnology and Engineering was introduced to the Chemical Engineering curriculum. This course was taught by a team of lecturers from School of Chemical and Metallurgical Engineering to final year Chemical Engineering students.

Conclusion

2.8. Theoretical framework

The theoretical starting point of the study is to find out the role of the University of Witwatersrand in the field of nanotechnology. The key assumptions that inform my framework are

- Assumption A: Globalization has changed the structure and the organization of knowledge production with universities have to cooperate or work with other institutions of research and training outside its boundaries. This opens more opportunities for the development of research and training in higher education institutions both globally and in South Africa by involving universities, not only in traditional teaching and research but also in nanotechnology entrepreneurial activities among their faculties members such as : "developing income-generating products and marketable services, consulting, business linkages, interdisciplinary partnerships and knowledge production in ongoing enterprises and producing income from technology transfer activities which provide intellectual property" (Slaughter and Leslie, 1997) in Subotzky (1999: 414)..

- Assumption B: The changing modes of knowledge production have also resulted in greater transdiciplinarity (transcending the boundaries between disciplines with experts from different disciplines working together) and greater interdisciplinarity (with participation of different disciplines in knowledge production of a particular field such as nanotechnology).

- Assumption C: The changing modes of production of knowledge have also resulted in greater prominence of application-driven research alongside primary research.

In the following section, I discuss these assumptions and their theoretical implications in more detail

Assumption A

This study is based on the assumption that the university alone cannot monopolize knowledge in the field of nanotechnology due to the interdisciplinary appeal of nanotechnology. Nanotechnology according to Uddin and Chowdhury (2001) is "truly

Interdisciplinary" and requires increased participations from multiple knowledge generating sites such as not just higher education institutions but government, civil society, research organization, business enterprises etc. The work of Gibbon et al (1994) and Scot (1995) are useful in this instance as they both highlight the need for other institutions apart from the university to participate in knowledge production. According to these writers, the shift from "Model 1" to "Mode 2" knowledge production means that higher education institutions will no longer dominate new knowledge and skills for the reason that they must compete with other public and private institutions. What this implies to this study is that the shift from "mode 1" to mode 2 has opened space for a variety of knowledge producers such as academics, business, government, civil society to participate in knowledge generation in the area of nanotechnology due to the multidisciplinary nature of nanotechnology. The study pays particular attention to this dimension in its analysis.

Assumption B:

The work of Gibbons (1998) helps to understand the need for university partnership in the area of nanotechnology. Gibbon highlights the importance of partnership and cooperation in knowledge. According to him, universities which "intend to practice research at the forefront of many areas are going to have to organize themselves to become more open, porous institutions, more aggressive in seeking partnerships and alliances, than they are currently"(Gibbons, 1998:10). The relevance of Gibbons' argument to this study is that it points to the need for examining the level of cooperation and partnership in the area of nanotechnology between the University of Witwatersrand and people located in other institutions such as industries, research institution, government and other universities. Where it occurs, this will mean a shift from the closed knowledge system characterised by the university to a much more open knowledge system and a growth in interdisciplinary and trans-institutional nanotechnology program. Academics will then be faced with the challenged of not just interacting with their academic colleague but with a range of other knowledge producers

in ensuring the effectiveness of student learning, curriculum development, research and training in the area of nanotechnology.

Assumption C:

Finally, Slaughter and Leslie (1997) maintain that there is an increasing role for application driven approaches in many spheres of research in the university, as most universities are moving away from basic research and heading towards more academic capitalism such as consulting, commercialisation of research results and intellectual property. The relevance of Slaughter and Leslie's argument to this study is that, apart from basic research, one must pay attention to how Wits has or has not privileged the applicability of research result in the area of nanotechnology. Integration of applied and primary research would certainly result in an increase in collaboration between Wits and Industry and the creation of new jobs in order to make the country and the university more competitive abroad. This would then mean that Wits would have to adopt aggressive commercialisation polices and encourage the development and ownership of intellectual property derived from research result.

The theories of Gibbon et al (1994), Gibbon (1998), Scot (1995) and Slaughter and Leslie (1997 provided the framework with which to analyse the role of university partnership in area of nanotechnology. Their works contributed immensely to my study, as they help to explain the need for partnership and collaboration between the university and different kind of knowledge producers and the need for applicability of research in the area of nanotechnology.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 Introduction

The purpose this chapter is to review the methodology and methods that were used in this study. O'Leary (2004) differentiates between methodology and methods. According to him, methodology is the plan for conducting research that includes methods and tools, while methods are described as the technique used to collect data, such as questionnaire, observation checklist, and interview schedule. This chapter therefore gives an overview of the research design and methods used in the study and their justification. The chapter also explains the instruments that were used to gather data, and gives reasons why the instruments were appropriate for the study. The issue of reliability, validity as well as the limitation of the study were also discussed in the chapter.

3.2. Research design

In order to investigate the role of the University of Witwatersrand in the field of nanotechnology, a research designed was used that involved the following main steps:

- Extensive literature review
- Document analysis
- Case study approach
- Instrumentation (semi-structured interview)
- Data analysis

Extensive literature review

The study reviewed extensive literature regarding the role of university partnership. The purpose of the literature review was to clarify issues around the need of university

partnership in the area of nanotechnology. For this reason, I have used extensive literature as source of secondary data as well as theoretical framework for my study. The information obtained from the literature was very useful as it provides theoretical and contextual insights into understanding the different perspectives on the data collected. In reviewing the literature, the following processes were used: getting information from published academic journals in Wits library as well as the internet, books and newspaper on the role of university partnership both in South Africa and International context.

Document analysis

Document analysis according to O'Leary (2004: 177) is the "collection, review, interrogation, and analysis of various forms of text as a primary source of research data". This can take the form of previously census data such as newspapers articles, official documents, policy documents, journals, books, historical archives, magazines, e-mails, memoirs, letters, sketches, drawings, photographs, diaries, memos, reports or company minutes. Cohen et al. (2000) refer to this process of data collection as methodological triangulation where different approaches are used in the same study. Bell (1999) also claims that documentary analysis is used to check the reliability of the study. For instance it can be used to check the reliability of the information received from interviews and questionnaire.

In order to investigate the role that Wits plays in nanotechnology various documents were collected from the Ministry of Science and Technology, government department and the University of Witwatersrand as data collection instruments. These include policy documents on science and technology, document on South African Nanotechnology Strategy, White paper document on higher education transformation in South Africa, University of Witwatersrand's mission statement, School of Chemical Engineering course content on nanotechnology. The policy and the strategy documents provided valuable information on technology and nanotechnology strategy, its development and implementation in South Africa. The University document provided information on the Wits mission and nanotechnology research and training activities at Wits. This method

of data collection is helpful in verifying the information obtained from the interview. In this way the validity of the study is ensured.

The case study approach

The case study is a particular method of qualitative research that provides a systematic way of looking at events, collecting data, analyzing information and reporting the results. As a result the researcher may have a better understanding of why the instance happened as it did and what might become important (Bell, 2005). The case study according to Bell (2005: 10) may be carried out by investigating how an organisation adapts to a new role or any innovation or stage of development in an institution.

The case study approach, however, has its limitation. For instance, according to Bell (2005: 11), some have questioned the value of single events and point out that it is difficult for researchers to cross-check information. Others raised the issues of selecting reporting and the distortion of information. In order to minimise this limitation, this study uses different types of data collection such as semi-structured interview and analysis of documents. Denzin (1984) calls this method of data collection above as 'methodological triangulation where one approach is followed by another to increase confidence in the interpretation of data. Yin (1994) also states that the need for triangulation arises from the ethical need to confirm the validity of the processes. Cohen and Manion (1994) are of the view that exclusive reliance on one method may bias or exhort the researcher's picture of the particular slice of reality she is investigating**.**

This study therefore used the case study approach to collect data from Wits academics on the role they play in the field of nanotechnology. In this respect, the study was limited to academics in the Faculties of Build and Engineering and Faculty of Science. Data for study was collected through semi-structured interview from four academics from the School of Chemical and Metallurgical Engineering and one academic from the School of Chemistry. These academics were purposefully selected because of the central role they

play in research and training in the field of nanotechnology. Some of these academics have 6 to 15 years experience in the area of nanotechnology.

Instrumentation (Interview)

According to Tellis (1997), interviews are one of the most important sources of case study information. Moser and Kalton (1997) cited in Bell (2005) describe interview as a conversation between interviewer and respondent with the purpose of eliciting certain information from the respondent. The study used the interview technique for data collection.

Various literature characterise interviews in terms of their degree of formality, ranging from unstructured through semi-structured to structured (Nunan, 1986). An unstructured interview is guided by the responses of the interviewee rather than the agenda of the researcher. The research exercises little or no control and the direction of the interview is relatively unpredictable. In a semi-structured interview, the interviewer has a general idea of where he or he wants the interview to go, and what should come out of it, but does not enter the interview with a list of predetermined questions. Topic and issues rather than questions determine the course of the interview. In the structured interview, the agenda is totally predetermined by the researcher, who works through a list of a set question in a predetermined order (Nunan, 1986). The advantages of using interview as opposed to other techniques are that it is flexible and adaptable. The disadvantages are that it allows for subjectivity and bias, it is time consuming, and involves high cost.

This study used semi-structured interview to collect data from academics in the University of Witwatersrand in order to find out the role they play in the field of Nanotechnology. For this purpose, open-ended questions sent through electronic mail (E-mail) were used to elicit information from the participants. The interview focused on the following issues:

- The emerging conception of nanotechnology within the University of Witwatersrand.
- The research and teaching role of the University of Witwatersrand in the area of nanotechnology.
- Challenges experience in the area of nanotechnology.

Five respondents from the University of the Witwatersrand represent different faculties and schools. Four of the respondents were from the Faculty of Engineering and Built Environment, the School of Chemical and Metallurgical Engineering, and one from the Faculty of Science, School of Chemistry. The participants were purposefully selected for the interview so that they could provide rich data concerning the research topic. Gay and Airasian (2000) state that qualitative researchers reply on purposive selection of participants to enrich their data. The participants have been chosen because of the central role they play in the field of nanotechnology. Purposive sampling tends to meet stated research goal, however, O'Leary (2004: 109) points out that it has its limitations in terms of being unwittingly bias and not representative. For ethnical reason, the respondents were assured of anonymity and confidentiality in the reporting of the data. In ensuring privacy, the names of the respondents were not mentioned in the study. In addition, the information obtained from the respondents was used for research purpose only, and was destroyed in all forms after the finalization of the study at all levels

3.3 Data analysis

Data Analysis according to Marshall and Rossman (1995) is "the process of bringing order, structure, and meaning to the mass of collected data". The answers to the interview questions were received by electronic mail. Since the sample for the study was small (5 respondents), it was very easy to analyse the data. The data was analysed using qualitative data analysis approach, employing thematic content analysis. Marshal1 and Rossman (1995) define the qualitative method as "a search for general statements about relationships among categories". Power (2002) views thematic content analysis as a means of categorizing, organizing and discussing data into theme for easy interpretation

and understand. Using the thematic content approach, I was able to categorize my data into themes with particular focus on the similarities and differences emerging the participants' responses to the interview questions. For instance, responses emanated from questions as to their role in the domain of nanotechnology ranged from teaching to research capacity building. Furthermore, because of the smallness of the sample for the study, reference were made to literature and documents on nanotechnology in order to obtain more information to support some of the views expressed by the respondents in the study.

3.4 Reliability and validity of study

The issues of reliability and validity are very central to qualitative research. Reliability according to Nunan (1986: 14) refers to the consistency of the results obtained from a piece of research. Similarly, O'Leary (2004) defines it as the extent to which a measure, procedure, or instrument provides the same result on repeated trial. Validity on the other hand, is the extent to which research actually investigates what the researcher purports to investigate. In other words, it is the extent to which the data we collected relates to and can answer the research questions that we asked. (Nunan 1986; O'Leary, 2004; Deem & Brehongy, 1994; Halpin & Troyna, 1994). Only when a measure is both reliable and valid that its results or scores can be confidently be used in research.

Various scholars have argued that in order to deal with reliability and validity threat and increase the credibility of a study, the following approaches should be considered: modus operandi approach, triangulation, feedback, member checks, Rich data, etc. (O'Leary, 2004; Nunan, 1986; Blanche et al., 1999; Maxwell, 1997). Blanche et al. (1999) point out that triangulation is considered to be one of the best ways of enhancing validity and reliability in qualitative research. Denzin (1989: 236) cited in Blanche et al., (1999: 275) supports this view, and according to him, triangulation,

> is the use of multiple methods, is a plan of action that will raise sociologists and other social science researchers] above the personal biases that stem from single methodologies. By combining methods and investigators in the

same study, observers can partially overcome the deficiencies that flow from one investigator or method.

In order to enhance the reliability and validity of this study, triangulation approach is used. Two methods of data collection are used in this study, such as interview and documentary analysis. The use of documentary analysis for instance will be helpful in verifying the information obtained from the interview

3.5 Limitation of study

This study is a qualitative case study. The limitation of this kind of study is that it is difficult to generalise from one case to another. For instance the respondents chosen for this study represents a small number of academics at Wits university that are currently involved in nanotechnology and therefore the information elicited from them might not necessarily represent the view of all Wits academics that are engaged in nanotechnology. The fact that students at Wits were not interviewed also posed a limitation to the study.

CHAPTER FOUR

4. CONTEXTUAL ISSUES

4.1 Introduction

This chapter presents contextual issues that might have led to the need for university partnership in the field of nanotechnology and the response of government in addressing the issue. They include external pressures at global level and internal pressures at national level. The global level requires that countries should adopt multidisciplinary, partnership and application based approaches to new technology. This has put pressure on country to come up with policy that supports such approaches. The main argument pursued in this chapter is that the interplay of global and national pressures has led to the need for partnership and application based approach in the area of nanotechnology in higher education institutions. Government's response to these needs was to come up with a national strategy on nanotechnology, which encourages a multidisciplinary and multi-institutional cooperation required to advance nanotechnology in the country. The following issues are discussed in the chapter:

- Globalisation and pressures in the Higher education system
- Nanotechnology in South Africa
- Nanotechnology at Wits

4.2. Globalisation and pressures in the higher education system

The post 1994 South African education system has undergone major restructuring due to global and national pressures. The recent developments in new technology and the need for flexible and innovative responses to rapidly changing global environment have put pressure on higher education to produce knowledge within various applied contexts (Gibbons et al. 1994; Clark 1998; Slaughter and Leslie 1997; Scot 1997; Subotzy, 1999, 2006; Waghid, 2002). The reason being that the traditional teaching and research role of

the university is inadequate to meet the demands of high-tech global competitiveness. As a result, government has encouraged collaboration among higher education institutions, industries, research councils and government. This has had a profound effect on the higher education research and graduate training in relevant field (Subotzky, 1999).

Similarly, recent development in nanotechnology has seen government in countries such as Britain, the United States of America, Belgium, Brazil, Australia, Germany, Canada, Japan, China, India etc coming up with initiatives that encourage collaboration among higher education institution, industries and government etc. For instance, Waters (2003) reports that there has been a significant increase in government support for nanotechnology research in universities in particular the new University Innovation Centre in Microsystems and nanotechnology at the universities of Newcastle and Durham and interdisciplinary research collaborations. . In Belgium, Waters also reports that the government has committed $15 million to its Nanotechnology programme to support a number of manor research project. For this purpose, the universities will work with research institutes in the first phase of basic research. A second phase will bring in industrial partner. In the United State of America, the government has provided funds to several government departments and independent agencies that support long-term fundamental research, the establishment of facilities/networks and the setting up of education/training programmes (Water, 2003). The Brazilian government has put together several existing high level nanotechnology research groups in several academic institutions and national research centres. Four research networks have been established with initial funds provided by the government for this purpose. (Singer et al. 2005).

In order to be in touch with global emerging technologies such as nanotechnology and to ensure sustainable economic growth, the South African government has created an enabling environment to promote nanotechnology activities in the country. A major step undertaken by the government includes the development of the South African nanotechnology strategy. To this effect, government has established a dedicated funding to support the implementation of the strategy, the encouragement of public and private sector partnerships, creating physical infrastructure to enable first-class basic research,

exploration of applications, development of new industries, and the commercialisation of innovation, encouraging the creation of interdisciplinary, and inter-institutional post graduate nanoscience and nanotechnology programmes, supporting the creation of strategic networks in the field of nanotechnology, and ensuring that the implementation of nanotechnology strategy occurs in a manner that fosters open debate and public access to information etc. (The Department of Science and Technology, 2006).

Singer et al. (2005) reports that 10 private companies are at present actively participating in the South Africa Nanotechnology Initiative. The areas of interest of the private sector in South Africa appear to be chemicals and fuels, energy and telecommunications, water, mining, paints, and paper manufacturing. For instance, companies such as Element Six, former De Beers, are currently optimising ultra hard nanomaterials for wear resistance in mining. Element Six has also developed nanosized alumina and Tin-containing composites and diamond and cubic boron nitride. In the area of energy, ESKOM is sponsoring research into fuel cells in preparation for alternative power generation and emergence of the hydrogen economy future. A case in point is the joint research project among ESKOM, the University of Western Cape and WRC in the area of water treatment technology using nanoscale filtration membranes for power plant technology. In the processing area, SASOL is already using Nanotechnology in their catalysts. SASOL has also funded research on nanophase catalyse in several South African higher education institutions, such as the University of Witwatersrand, University of Western Cape, University of Natal, University of Port Elizabeth and University of Cape. Johnson Matthey, Anglo Platinum and Su-Chemie SA have all shown interest in energy conversion such as oil, gas to liquids, fuel cell reactant gas clean up, solar energy processes, catalysts as beneficiated minerals (gold, platinum group metals, Zirconium, titanium) and environmental (The South African Nanotechnology Initiative, 2003).

The vision of the White Paper on higher education transformation in South Africa is that higher education "must provide education and training to develop the skills and innovations necessary for national development and successful participation in the global economy" and must be "restructured to face the challenges of globalisation" (cited in

Subotzky, 1999, p. 412). The South African nanotechnology strategy is in line with the vision of the White Paper on higher education. Currently several higher education institutions are involved actively participating in the national initiative. They include the University of Cape Town, the University of the Witwatersrand, the University of Pretoria, the University of the North, the University of the Western Cape, the University of Kwazulu Natal, University of North-West, University of Stellenbosch, University of the Free State, University of South Africa, Vaal University of Technology and Techikon Pretoria, For instance, the University of Cape Town is involved in research into solar cell development using nanotube,, the University of Western Cape and University of Zulu research in water treatment technology using nanoscale filtration membranes. UWC also has research cooperation with ESKOM in the area of effluent treatment using nanophase electro catalysts for anodic decomposition of organic pollutant. The University of Witwatersrand is researching into carbon nanotube, mico and nano composites (including ceramics) with emphasis on electrical dielectric, magnetic and super conducting properties (The South African Nanotechnology Strategy, 2003). The table in the next page shows in detail Nanotechnology research activities in Tertiary Education Institutions in South Africa.

Table 4.1: Nanotechnology research activities in tertiary education institutions in South Africa.

Tertiary Education Institution	Nanotechnology related Focus	Nanotechnology related Outputs, competencies
University of the North	Computational Modelling for advanced Materials Design	The onset of metallic Behaviour with growing system size.
University of Natal	Modelling carbon nanotube and based nanocomposites using a continuum approach.	Expertise in nanocomposites.
University of Port Elizabeth	1. Nanocomposite from Beta and Polypropylene Matrices. 2. Micro-analytical and micro-structural characterization materials.	Expertise in analysis of fibre reinforced composite. Micro-analytical and micro-Structural characterization Materials. Platinum-aluminium alloys and nanogold particles. Ceramic-metals and cadmium-titanium carbide compounds etc.
University of Pretoria	Nano-wires and Quantum Dots	Manufacturing and Characterisation of nano-Wires and quantum dots on Semiconductor materials using ion bombardment.
Technikon Pretoria	Use of single-walled carbon nanotube as catalyst support	Production and purification of carbon nanotubes. Design and construction of related apparatus (e.g. carbon arc apparatus, purification apparatus, catalysts test rigs, etc.)
Medical University of South Africa (MEDUNSA).	Prepared and used nanotubes as catalyst supports encapsulation of nanotubes with metals such as gold and platinum was performed.	Research of nanotubes and Fullerenes, constructed Instrument to manufacture Same.

Table 4.1 contd. Nanotechnology research activities in tertiary education institutions in South Africa.

Tertiary Education Institution	Nanotechnology related focus	Nanotechnology related Outputs, competencies
University of the Witwatersrand	1. Synthesis and Characterisation of self-assembling nano-composites.	Advanced crystallographic/XRD characterisation-including single crystal and powder.
	2. Properties of Nano-Materials Under Extreme Conditions of High Pressure and Temperature.	Mossbauer magnetic-electronic characterization of iron-based. Nano-phases in mineralogy, chemistry and materials science. High pressure-temperature investigations of nano-materials;
	3. Intelligent and competitive emerging Nano-technologies for Green/ environmental and friendly energy sustainability based on titanium and vanadium derivatives.	
	4. Mico and nano-composites (including ceramics) with an especial emphasis on electrical, dielectric, magnetic and super conducting properties.	Percolation conductivity and impedance spectroscopy of single walled nano tube polymer composites.
	5. Carbon nanotube.	Production of carbon Nanotube.
	6. Microstructural characterisation	Microstructural Characterisation by electron (TEM, SEM, EDS, EELS), and atomic force microscopy of intermetallics, platinum alloys, hard metals and nano-particle materials.

Table 4.1: contd. Nanotechnology research activities in tertiary education institutions in South Africa.

Tertiary Education Institution	Nanotechnology related Focus	Nanotechnology related Outputs, competicies
University of the Witwatersrand. Contd.	7. Heterogeneous catalysis	Heterogeneous catalysis, fabrication of nanostructures, structure = activity relationships in heterogeneous catalysis and haracetrization of solids. Activation and conversion of small alkanes, nanogold catalysis, catalysis by zeolites.
University of Zululand	Synthesis of Nanoparticles And Polymer Nano-composites	Synthesis of semiconductor quantum dots and nano-Composites.
University of Stellenbosch	Nanocomposites and Macromolecules	1. Biomedical – including Bactericides; anti-tumour agents; prosthetic devices for the vascular system operations; re-absorbable wound dressings; re-absorbable burn dressings 2. Reinforcement of glassy materials for stress banding through the synthesis of novel monomers, which self-assemble 3. Biomimetic knowledge studying self-assembly of 3D structures such as would happen in the human body 4. Nano fibres devices for removing toxic materials from water and other liquids harmful to human beings.

Table 4.1: contd. Nanotechnology research activities in tertiary education institutions in South Africa.

Tertiary Education Institution	Nanotechnology related Focus	Nanotechnology related Outputs, competencies
University of Stellenbosh. Contd.	Nanocomposites Macromolecules	5. Novel new analytical equipment for studying Nanophases and nano-thickness films including: a. ultrasonics and its use non-destructively b. the atomic force microscope not only for topography but for phase transitions in nanodomains (no other technique does this) 6. Nano mini-emulsions for the preparation of self-assembly block polymers which in small amounts can modify paints and adhesives 7. Positron annihilation used to determine free volume and access free volume in polymer surfaces, e.g. the ageing of high voltage insulators.
University of Cape Town	1. Solar cell development using Nanotechnology	Thin film characterisation, naostructures in solids, amorphous and nanocrystalline silicon, star cells, devices positron annihilation analysis

Table 4.1: contd. Nanotechnology research activities in tertiary education institutions in South Africa.

Tertiary Education Institution	Nanotechnology related Focus	Nanotechnology related outputs, competencies
University of Cape Town. Contd.	Heterogeneous Catalysis Catalytic process Development	1. CATALYSIS – synthesis, characterization and testing. Nano-scale relating principally to 2-15 nm scale supported metal crystallites where transition from metal to metal-oxide interface occurs depending on chemical environment. Preparation of nano-crystals, size distributions determination and stabilization of active phases. Application to industrially applied large-scale chemical processing. 2. MOLECULAR MODELLING. Specially related to gold catalysis (including commitment to USA –RSA gold collaboration) and shape selectivity in zeolite catalysed processes. 3. SEMICONDUCTORS (historical) –growth of defined 2-dimensional crystalline structures including repetitive structures on the scale 2-20 nm. Application in microelectronic semiconductor devices (infrared detectors).

Table 4.1: contd. Nanotechnology research activities in tertiary education institutions in South Africa.

Tertiary Education Institution	Nanotechnology related Focus	Nanotechnology related Outputs, competencies
University of the Western Cape.	1. Solar cell development using Nanotechnology	Solar cell development using Nanotechnology Developed technique for cross sectional electron microscopy of any surface films and interfaces.
	2. Nanophase catalysts, electrocatalysts applied in fuel cells, exhaust gas treatment, chemicals production, waste water treatment.	New inorganic proton-conductive Membranes for hydrogen Separation and electro-catalysis
	Nanophase catalysts, electrocatalysts, nanocomposites applied in hydrogen production and other catalytic processes	Experienced in nano particle Preparation and characterization. Manage Eskom Materials Technology project: Nanostructured catalysts and membrane reactors for electrosynthesis.

Nanotechnology Nanotechnology Strategy, 2003.

This database published in the 2003 Nanotechnology Nanotechnology Strategy revealed that the South African Universities have started building the required critical mass in the domain of nanotechnology for sometime now.

4.3. Background on nanotechnology at Wits

Presently, three (3) faculties are involved in nanotechnology activities at the University of Witwatersrand. They include the following faculties:

- Faculty of Engineering and the Built Environment
- Faculty of Science
- Faculty of Health Science.

The faculties of Engineering and the Built Environment are involved in research and teaching in nanotechnology, while the faculty of Science and Health Science are at the moment focussing mainly on research activities. The information obtained from some of the respondents in the study indicates that the faculty of science and health science are not involved presently in teaching in the area of nanotechnology because the field is still new and that they will be faced with the challenge of providing students with a broad understanding of not only the basic sciences but engineering sciences as well.

Faculties of Engineering and the Built Environment

Within the Faculties of Engineering and Built Environment, academics from the School of Chemical and Metallurgical Engineering are involved in teaching and research in Nanotechnology. In research the focus area is on production of carbon nanotube for industrial application. The school has a number of seven postgraduate students research in nanotechnology. These students are from different disciplines, such as Chemistry, Biology, Pharmacy, Electronic, Chemical and Metallurgical Engineering. The Centre of Excellent in Strong Material under the Department of Science and Technology mainly funds the research project. The School of Chemical and Metallurgical engineering is also involved in joint research project in the area of carbon nanotube with Vaal university of Technology, Air Product and South Africa Brewery, with the project mainly funded by these institutions.

In teaching, a course known as "Carbon nanotechnology and Engineering", Advanced Chemical Engineering D was introduced into the Chemical Engineering curriculum and was taught for the first time to the third and final year chemical engineering student in the first semester of the 2006 academic year. Three academics with geology, metallurgical and chemical Engineering background taught the course. A total number of 86 students took the course, with 97% of students passed the course and the remaining 3% failed the course.

Faculty of Science

In the faculty of Science, the school of Chemistry for instance is involved in research in synthesis and characterisation of self-assembling nanocomposites, heterogeneous catalysis, fabrication of nano structures and funded by National Research Foundation. The School of Physic is involved research into properties of nano-materials under extreme conditions of high pressures and temperature, and research into intelligent and competitive emerging nanotechnologies for green/environmental and friendly energy sustainability based on titanium and vanadium derivatives. Fund for research activities mainly come from National Research Foundation

Faculty of Health Science

The School of Pharmacy is involved in joint research collaboration in the area of carbon nanotube for drug delivery with the school of Chemical Engineering. In this collaboration, the School of Pharmacy uses the carbon nanotubes produced in the School of Chemical and Metallurgical Engineering for drug delivery. The constraint currently faced is the in vivo trials, which requires lengthy protocol for ethical approval.

Table 4.2 in the next page presents the number of Faculties and Schools that are involved in nanotechnology activity at Wits

Table 4.2: Faculties and Schools that are involved in nanotechnology activities at Wits

Faculty	School	Activities	
		Teaching	Research
Engineering and the Built Environment	Chemical and Metallurgical Engineering.	Yes	Yes
	Mechanical and Aeronautical Engineering		Yes
Science	Chemistry		Yes
	Physics		Yes
Health Science	Pharmacy		Yes
	Medicine		Yes

4.4 Conclusion

In providing the contextual background, this chapter has shown that the development of new technology and innovative responsiveness to rapidly changing global condition has made government to put pressure on higher education institutions to produce knowledge within various applied context. This has resulted in the proliferation of nanotechnology research and training in several South African universities and that the development of these were not accompanied with similar efforts to develop strong inter-institutional and cross-sector collaborative activities. Nonetheless, the chapter reveals active involvement of the South African government, the universities and industries in the area of nanotechnology. The government has established dedicated funding in support for research collaboration in the area of nanotechnology. Responding to government call for participation in the national initiative, both industries and higher education have shown interests in numerous research areas in nanotechnology. The University of the Witwatersrand has also responded to this by providing research and training in the nanotechnology. However they are faced with limited number of academics involvement in the national initiative.

CHAPTER FIVE

5. THE SOUTH AFRICAN NATIONAL NANOTECHNOLOGY STRATEGY

5.1. Introduction

This chapter aims to describe and analyse the development and the implementation of the South African National Nanotechnology Strategy. The chapter argues the need for nanotechnology as a result of globalisation has put pressure on the government to develop a South African National Nanotechnology Strategy. The chapter reviews the South African Nanotechnology Strategy. Generally, it explores the following issues:

- The development of the South African Nanotechnology Strategy
- Implementation of the Strategy

5.2. The development of nanotechnology strategy in South Africa

The need for new technology, due to global pressures has led to the South Africa government to develop a technology policy. Since the publication of the White Paper on Science and Technology in 1996, the government has made great efforts to accelerate the role played by science and technology in bringing about sustainable economic development (White Paper on Science and Technology, 1996). One of the efforts made by the government is the development of the South African National Nanotechnology Strategy. The aim of the strategy is to "ensure that South Africa is ready to optimally use nanotechnology to enhance her global competitiveness and sustainable economic growth" (The Department of Science and Technology, 2005). The strategy is still very new, as it was only approved by the cabinet in December 2005, and officially launched in April 2006. For now it cannot compete with well established nanotechnology strategy in the United States of America, Australia and Japan. The South African government believes that:

> Nanotechnology in South Africa would create opportunities for human capital development, particularly for historically disadvantage individuals (HDIs), women and people with disabilities. It would also drive research and development; innovation, education, training and curriculum development; innovative entrepreneurship and improved opportunities for BEE (Department of Science and Technology, 2006:5).

In order to optimise the opportunities of nanotechnology, the South Africa government has created an enabling policy environment. For instance, the government, through it department of science and technology (DST) in April 2003 commission a group f experts known as the South African nanotechnology initiative (SANI) to develop a South Africa Nanotechnology Strategy for submission to DST. The process of formulating the South African nanotechnology strategy was underpinned by the principle of participation, interaction and consultation. The strategy was broadly represented. For instance a wide range of stakeholders from industries, higher education institutions, government, research council and students worked as a multi-disciplinary team to formulate the strategy.

Since the stakeholders would be responsible for implementing the strategy, the government felt the need of involving them actively. In addition, involving the stakeholders will encourage a sense of ownership and commitment to the development of the strategy. This is in line with Mortimore's (2000) claims that "those who are close to a particular development are in a good position to recognise its problem. Below is the table showing the people that constituted the expert team that developed the strategy in consultation with many others. One expert each from higher education institution, industry, research council and government participated in the formulation of the strategy. Thus at the implementation stage, the University of the Witwatersrand has been involved in teaching and research in nanotechnology. For instance Wits has a centre that coordinates and collates all teaching and research activities in nanotechnology.

Table 5.1. Composition of expert team involved in the formulation of the July 2003 South African National Nanotechnology Strategy Draft

Affiliation	Expert
University of Cape Town (UCT)	Dr David Britton
University of the North (UNIN)	Prof Phuti Ngoepe
University of Stellenbosch (US)	Dr Ron Sanderson
University of the Western Cape (UWC)	Ms Leslie Petrik
University of the Witwatersrand (Wits)	Dr Malik Maaza
University of Pretoria (UP)	Mr George Makino (Student)
University of Manchester (MU), United Kingdom	Prof Paul O'Bien
University of Technology, Sidney (UTS)	Prof Mike Cortie
University of Western Cape	Lindiwe Khotseng

Affiliation	Expert
Department of Science and Technology (DST)	Ms Pontsho Maruping
National Research Foundation (NRF)	Dr Prins Nevhutalu
Element 6 (E6)	Dr Jack Sigalas
SASOL	Dr Humphrey Dlamini
ESKOM	Mr Gerhard Gericke
CSIR	Mr Manfred Scriba
MINTEK	Mr Molefi Motuku
Advanced Manufacturing Technology Strategy Team (AMTS)	Mr Sushil Borde
University of Pretoria	Mr George Makino (Student)

In formulating the South African nanotechnology strategy the government consulted the South African nanotechnology Initiative (SANI). On June 10 2003, SANI appointed expert group and formed a steering committee. In June, 2003 SANI workshop was held to consults with representatives of the Nanotechnology community on the needs and problems in developing nanotechnology strategy. In Gauteng between 14-18 July 2003, another workshop was conducted. Input from this workshop was used to formulate the strategy. SANI proposed a technology innovation network to help support the implementation of the nanotechnology strategy. The following 10 recommendations were made:

- Set up a strategic Nanotechnology fund to supports
    - the development of human resource capacity
    - build research and development capacity
    - establish networking and shared resources
    - stimulate innovation, incubation, and technology transfer, including the growth of BEE and SMMEs.
    - create transparency and public awareness of Nanotechnology.
- Stimuate final year undergraduate students, MSc, PhD and Post-Doctorates with Bursaries and incentives to bring about HR explosion in Nanotechnology.
- Create interdisciplinary and inter-institutional postgraduate programmes in Nanoscience and Nanotechnology.
- Strengthen industrial HR Nanotechnology capacity with training programmes and internships.
- Stimulate pre-competitive R& D in Nanoscience and Nanotechnology.
- Implement Strategic Networks and management structures in Nanoscience and Nanotechnology.
- Plan for and acquire capital and other necessary equipment.
- Make provision for communication, mobility and access to facilities, and operation of equipment.
- Adopt an approach to taking technology from the research environment to industrial production and benefit generation by a long term focus on poverty alleviation.

– Provision for awareness generation, regulation and monitoring, including special initiatives such as a flagship project. (South African Nanotechnology Strategy, 2003).

The recommendation was submitted for further stakeholder deliberation and consultation. Having received comments and suggestion on the report of the draft strategy, the Department of Science and Technology then submitted to the Ministry for approval. In December 2005 the strategy received the approval of the cabinet and was officially lunched in April 2006. Figure 5.1 below shows the process used in developing the South African Nanotechnology Strategy.

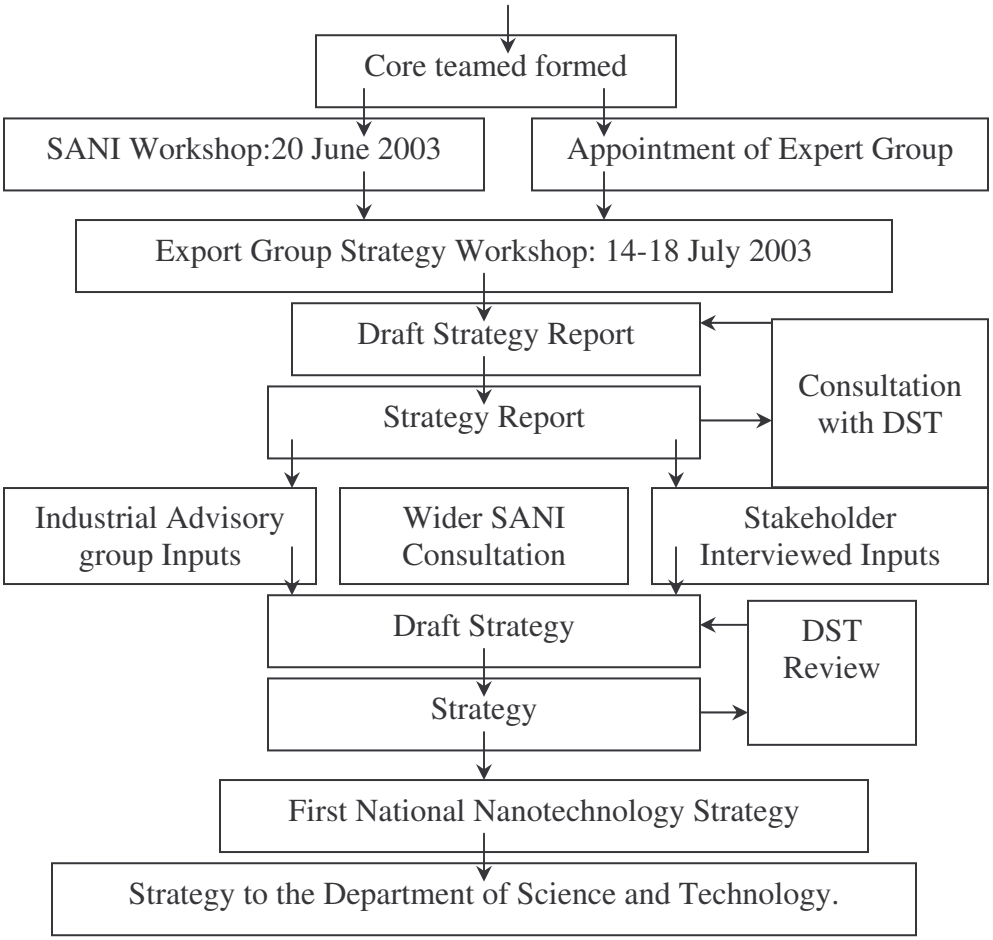


Figure 5.1. The nanotechnology strategy development process.

A Particular and important feature of South African National Nanotechnology development process is the diverse make up of the expert team that are involved in the formulation of the strategy. The open, interactive and collective mode of operation adopted by the expertise team despite their different background contributed immensely to the success of the strategy, and thus helped pave the way for government approval of most of the recommendation made on the strategy.

5.3. Implementation of the strategy

This section examines the implementation strategies used by the government, higher education institutions, and industries in promoting nanotechnology activities in South Africa. The South African government through its Department of Science and technology came up with the following implementation strategies:

- The establishment of characterisation centres
- The creation of research and innovation networks
- Capacity building initiatives
- A number of flagship projects

The government aims to establish Characterisation Centres, which will be geographically distributed and contain multi-user facilities. The Centres will provide researchers with advanced instruments for design, synthesis, characterisation, modelling and fabrication. In the case of research and innovation networks, the government plans to create research and innovation networks that will serve to enhance collaboration among traditional disciplines, research teams and institutions. On the issue of capacity building, the government has come up with initiatives that are aimed at developing human capacity resources through channelling public and private sector investment towards undergraduate and post graduate research, encouraging interdisciplinary and inter-institutional postgraduate programme in Nanoscience and Nanotechnology and supporting collaborative research and development in nanosciences. In terms of Flagship Project, the government has also come up with a number of flagship projects that are

aimed at demonstrating the benefits of Nanotechnology towards an enhanced quality of life and increased economic growth. These will initially focus on water, energy, health, chemical and bio processing, mining and minerals as well as advanced manufacturing. (Department of Science and Technology, 2005).

In order for South Africa to enjoy the benefits of Nanotechnology, the government has felt the need for a substantial investment in the area of Nanotechnology. For this research, the government, through its Department of Science and Technology and its appointed agency such as the National Research Fund have allocated R450 million over the next 3 years to be utilised for human resource and research capacity development as well as the commercialisation of Nanotechnology innovation products in the country. The budget for the successful implementation of the Nanotechnology strategy is shown in the table below:

Table 5.2: Budget for the implementation of the South African Nanotechnology Strategy

Cross-cutting S&T Frontier Programmes	2006/7 R000	2007/8 R000	2008/9 R000
Capacity Building (R&D and HRD)	30,000	60,000	80,000
Research and Innovation Networks	10,000	20,000	20,000
Flagship Projects	20, 000	30,000	50,000
R & D Infrastructure			
Characterisation Centre	40,000	40,000	50,000
Total per year	100,000	150,000	200,000
Total for 3 years			**450,000**

(Department of Science and Technology, 2005).

In terms of industries supported initiatives, there are few initiatives. For instance there is an on going research focus on nanophase catalyst funded by SASOL in South African higher education institution. These institutions include: the University of Witwatersrand,

the University of Cape Town, the University of Western Cape, the University of Kwazulu Natal and the University of Port Elizabeth. There is also a joint ESKOM, UWC, and WRC project on effluent treatment using nanophase electro catalyst for anodic decomposition of organic pollutant. Element six, is also currently optimising Ultra hard nano materials for wear resistance. PPM (Pty) Ltd is presently in contact with Wits to up-scale a locally developed manufacturing process of nano Ti02 particles.

Higher education institutions have received fund from government to develop human resource and research capacity in the area of nanotechnology. As a result of the pressure from government, most South African universities and technikons are now involved actively in Nanotechnology activities. These institutes include University of Pretoria, the University of the Witwatersrand, the University of Cape Town, the University of the North, the University of Pretoria, the University of Kwazulu Natal, University of Western Cape etc have been proactive in implementing the strategy. For instance the University of Western Cape through partnership with ESKOM is involved in water treatment technology using nanoscale filtration membranes. The University of the North has a strong focus on developing computational Modelling for advanced design materials. The University of the North is also involved in research and manufacturing and has numerous publications in international journals in the area of nanotechnology. Technikon Pretoria is involved in the production and purifications of carbon nanotubes. The University of Witwatersrand is involved in numerous research and training program in the area of nanotechnology (Iyuke et al. 2006). For instance the Wits has made provision for short courses in nanotechnology and the integration of nanotechnology into its Chemical Engineering curriculum, publication of paper on nanotechnology and numerous technical reports for South Africa industries such as AAEL, Water SA, on the characterization of iron-bearing compound.

The implementation strategy of the government which includes for instance the development of human resource capacity in the area of nanotechnology has not been fully implemented. There is still not enough trained work force, as only few number of universities offer courses in nanotechnology. In addition only few industries have

invested in training and research in nanotechnology. For successful implementation of the strategy in higher education, there is a need for government and private sector to establish a dedicated funding for the support of the strategy.

5.4. Conclusion

The need for nanotechnology resulting from globalisation has put pressured on the South African government to develop a National Nanotechnology. The government believes that various stakeholders such as higher education institutions, industries, research councils, government and students have a role to play in ensuring that South Africa optimally uses Nanotechnology to enhance her global competitiveness and sustainable economic growth. The process of formulating the South African Nanotechnology Strategy is underpinned by the principle of participation and consultation with various experts from South African and foreign universities, research council, students, and government equally participated in formulating the policy. Furthermore, the chapter reveals that various stakeholders have adopted a more proactive approach in implementing the strategy. However, in the case of higher education institution, there are still limited numbers of academics who are involved in the implementation of the strategy, and this will pose a serious problem of sustainability.

CHAPTER SIX

6. THE ROLE OF THE UNIVERSITY OF WITWATERSRAND IN THE FIELD OF NANOTECHNOLOGY

6.1. Introduction

The aim of this chapter are to discuss and analyse the general conceptions of Nanotechnology at the University of Witwatersrand (Wits), the role it plays in nanotechnology and the challenges it faces. The chapter argues that for Wits to play a more effective role in research and human resource capacity development in the field of Nanotechnology, there is a need to cooperate and partner with other knowledge producers such as government, industries, research councils and other universities. Collaboration of this kind is necessary, when one takes into consideration the multidisciplinary and interdisciplinary nature of Nanotechnology and the shrinking resources available for university research. Furtherer the views of the respondents are also examined in this chapter. The chapter therefore focuses on the following issues:

- General Conception of Nanotechnology at the University of the Witwatersrand.
- The role of the University of the Witwatersrand in the field of Nanotechnology.
- The challenges the University of the Witwatersrand faced in the area of Nanotechnology.

6.2. General conception of nanotechnology at the University of the Witwatersrand

The South African National Nanotechnology Strategy highlights the importance of transparency and public awareness in the field of Nanotechnology (Department of Science and Technology, 2005:3). Another issue raised in the South African Nanotechnology Strategy as well as the White Paper on Science and Technology is the need of addressing a problem-solving, multidisciplinary, partnership to innovation as a

mechanism for growth and development. Both the Strategy and the White Paper mentions that the traditional ways of producing knowledge within single disciplines and institutions should be supplemented by knowledge generated within various applied contexts. This is the knowledge that is collaboratively created within multidisciplinary and transdisciplinary research program that includes knowledge generating sites and institutions such as higher education institutions, government, research organisation and private sector (The White paper 1996: 4-5).

The information obtained from the respondents indicates that, although the field of nanotechnology is somewhat incipient within the university domain in South Africa, there is a growing awareness of Nanotechnology research and training at the University of the Witwatersrand (Wits). They say Nanotechnology at Wits has some element of multidisciplinarity and interdisiciplinarity. In terms of multidisciplinarity, they claim that Nanotechnology at Wits is multidisciplinary in nature because a variety of Science and Engineering disciplines such as the Faculties of Engineering and Built Environment, Science and Health Science are involved in Nanotechnology research. For instance, one of the respondents in the study claims that:

> Different faculties such as Science and Engineering are involved. For instance there is a strong group in Chemical and Metallurgical Engineering producing nanotubes and another group in Chemistry using it for catalyst support. I think there is a good grasp of what Nanotechnology is about at Wits.

Some respondents in the study attest to the limited interdisciplinary and inter-institutional collaboration of Nanotechnology activities at Wits:

> The situation at Wits is that many disciplines such as Chemical and Metallurgical Engineering, Mechanical and Aeronautical Engineering, Pharmacy, Physics and Chemistry are involved in Nanotechnology research without much interaction among these disciplines. We need more collaboration among different faculties in the area of research and training in nanotechnology.

6.3. The role of the University of Witwatersrand in the field of nanotechnology

The University of the Witwatersrand has played a significant role since the inception of the South African Nanotechnology initiative. Its role includes that of providing human resource and research capacity, in some cases through partnership with other knowledge producers. In terms of the involvement of Wits in education and training in Nanotechnology, one of the respondents in the study claims that:

> A new course known as Carbon Nanotechnology and Engineering: Advanced Chemical Engineering D was introduced in the first semester of the 2006 academic session into the Chemical and Metallurgical Engineering curriculum. A total number of 86 students took the course. The students were 3rd and final year Chemical Engineering students. Three experts who taught the course were Geologist, Metallurgist and a Chemical Engineer from Wits. The objective of the course was to identify and design production technique for carbon materials for small and industrial application. The Course also provided students with additional and richer opportunities to engage in activities that would stimulate creative and critical thinking skills in the field of Nanotechnology. 93% of students passed the course and there was general acceptance of the course by the students.

Furthermore, the respondents in the study also say that Wits has organized short courses in Nanotechnology. For example:

> A 3 day workshop on "Introductory Nanotechnology" was organized by the School of Chemical and Metallurgical Engineering from 19th to 21st of October, 2005, drawing participants from the Universities and Industries, both locally and internationally. The participants were from the United Kingdom, Netherlands, Mozambique, Nigeria, Federal Republic of Congo and South Africa. The aim of the course was to provide an introduction to the field of nanotechnology. Furthermore, another 3 day short course on Carbon Engineering and Nanotechnology was held from 2nd to 4th of April, 2007 at Wits. The course aims to disseminate the knowledge from academic programme more broadly and to provide an introduction to the field of carbon engineering and nanotechnology. The course also brings together theories and the most up to date research findings on the unique

> properties, practical synthesis, coals as carbon source, and real applications for most types of carbon-related nanomaterials and technology. It surveys carbon-based nanomaterials currently in use, as well as future applications in the fields including energy storage, pharmacy, medicine, IT and Communications, sensing, molecular electronics and micro electromechanical devices. Participants were drawn from industries (Energy Utilities Regulatory Company, research councils (CSIR) and the Universities (Vaal University of Technology, Wits).

With regards to research, the respondents in the study maintain that they have been involved in basic research in the area of nanotechnology. One of the respondents in the study says:

> I have been involved in research in nanotechnology such the production of carbon nanotubes and have several publications on nanotechnology in local and international journal, as well as several publications local and international conference presentation on nanotechnology. Funds for our research activities normally come from Centre of Excellent (CoE) in Strong Material under the Department of Science and Technology. Some academics in Wits are researching into synthesis and characterisation of self-assembling nanocomposites, properties of nano-materials under extreme conditions of higher pressure and temperature, intelligent and competitive emerging nanotechnologies for green/environmental friendly emerging sustainability based on titanium and vanadium, Micro and nano composites, heterogeneous catalysis and fabrication of nanostructure. Funds for their research also come from government, and industries such as Element 6, SASOL and ESKOM.

Another respondent claim that:

> My main research interest in the area of nanotechnology is on characterisation and processing of fine powders for the making of ceramic bodies with nanosized grain sizes.

The study also reveals that Wits encourages inter-faculty research in the area of nanotechnology. For instance a respondent from the School of Metallurgical Engineering says:

> In line with the interdisciplinary nature of nanotechnology, my faculty has attracted 7 post-graduate students from different academic background such as biology, chemistry, pharmacy, chemical, metallurgical and electrical engineering. These students are involved in nanotechnology related research.

The University of the Witwatersrand has a favourable policy towards research cooperation. The study reveals that Wits promotes research cooperation in the area of nanotechnology. The research cooperation ranges from academic cooperation with other universities as well as industrial cooperation. . For example, a respondent from the School of Chemical and Metallurgical Engineering says:

> My School has entered research collaboration to pursue joint research cooperation with Vaal University of Technology (VUT), Air Product South Africa, and South Africa Brewery. The research collaboration with Vaal University is established principally with the department of electrical and electronic engineering. The purpose of the collaboration is to use carbon-nano tube for the fabrication of fuel cell component such as electron. The overall collaboration between Wits and Vaal University is beneficial, since Wits receives its share of benefit in terms of financial input while Vaal University receives the most up-to-date knowledge, experience and technique on Nanotechnology from Wits. Collaboration with Vaal is very much based on individual researcher contact with Vaal University. Informal contact plays very important role for collaboration pattern in Wits. In addition, Wits is also involved in consulting activities. A good example is the extensive analytical service provided by School of Physic in the area of Nanotechnology to Mining and Chemical Industries.

Another respondent claim that:

> My School collaborates with the Institute of Ceramic Technologies and Systems, of the Fraunhofer Society, Dresden, Germany. The collaboration is on processing of nanosized powders since 2000.

In terms of patenting, the study shows that the School of Chemical and Metallurgical Engineering has patented findings from work on Nanotechnology. According to one of the respondents:

> My School has patented finding from work on Nanotechnology. This is a break through for the University, as it will generate larger income for the University.

Another respondent says:

> Presently, Wits approach to research in Nanotechnology is purely academic, although there is also a bit of commercial interest in my Faculty to patent findings from their work. I think, this cautious approach is beneficial, as long as it does not stifle research in the university.

In summary, it appears that researchers at Wits University tend to privilege primary or basic research undertaken for scholarly purposes, though there are attempts to explore the commercial value of nanotechnology research. Generally, there are limited collaborative projects with other researchers and institutions at both national and international levels which depend on the initiative and efforts of individual researchers. These two areas pose a considerable challenge to Wits University with immense unexplored opportunities.

6.4. The challenges the University of the Witwatersrand faced in the area of nanotechnology

The study also revealed the various challenges faced by the University of the Witwatersrand in the area of Nanotechnology. One of the challenges according to the respondents is the limited number adequately trained academics involved in Nanotechnology activities. A respondent in the study says:

> At the moment, only few academics are involved in either research or teaching in nanotechnology. In order to provide the type and grade of Engineering and Science students in the area of nanotechnology, I think there is a need for more academics to be involved in training of students, rather than relying on such a few.

Chang (2002) and Uddin and Chowdhury (2001)) stressed the need of including Nanotechnology into the Engineering curriculum. Chang (2002) argued that in order to

keep up to the speed at which innovations and inventions are generated, there is an unprecedented demand of highly educated and trained engineers in the field of Nanotechnology. Similarly, the respondents in the study argue for the integration of nanotechnology into the Engineering and Science curriculum. One of the respondents says:

> I support the inclusion of Nanotechnology into the Engineering and Science curriculum. I think having a course on nanotechnology would be very good for undergraduate Engineers and Scientists. Good exposure to new ideas and field.

Another challenge faced by Wits as revealed in the study is that only limited numbers of productive and industrial sectors are involved in research collaboration with Wits:

> The current situation at Wits regarding collaboration with industry is that there have been some cases of Wit-industry collaboration in the area of nanotechnology, though not on a large scale. We need to work together with industries as one unit, with a common project and with the aim of developing new products for industries. The purpose of collaboration should not only be limited to research and development but should include improving the quality of teaching and learning in the area of Nanotechnology at Wits.

6.5. Conclusion

The chapter has explored issues around the general conception of Nanotechnology at the University of Witwatersrand (Wits), the role Wits plays in Nanotechnology and the challenges it faces. The chapter has shown that there is a growing awareness of Nanotechnology at Wits, especially among the Faculties of Engineering and Built Environment, Health Science and Science. As regards the role of the University of the Witwatersrand in the field of Nanotechnology, the study reveals that Wits some Schools have been proactive in providing research and human development capacity in Nanotechnology. However, the chapter has also shown that there are limited numbers of academics who are involved in Nanotechnology activities at Wits. The need for more collaboration between Wits and industries are also highlighted in the chapter.

CHAPTER SEVEN

7. CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

The purpose of this study was to investigate the role of the University of the Witwatersrand (Wits) in the field of Nanotechnology. This chapter provides a summary on the important issues that are highlighted in the study. These include the main argument of the study, the issue of globalisation and its effects on the role of the university in the field of nanotechnology, the contextual issues that led to Wits involvement in Nanotechnology, the South African Nanotechnology Strategy, the emerging conception of Nanotechnology at Wits, as well as the experiences and challenges Wits faced in the area of Nanotechnology. Several theoretical insights can be drawn from the study.

Firstly, the study has argued that the teaching and research role of the University of the Witwatersrand in the area of Nanotechnology can be enhanced more effectively through collaboration with knowledge producers in other universities, research institutes, government, industries and civil organisation. This is because of the interdisciplinary appeal of nanotechnology. It has shown that globalisation-related developments such as the changing modes of knowledge production and the emergence of the entrepreneurial university have changed the way knowledge is being produced in the context of higher institutions. Evidence from literature showed that globalisation has led to a strong tendency towards entrepreneurial university, and this has also resulted in university management encouraging entrepreneurial activities among faculty. This has opened more opportunities for the development of research and training. It has led to university encouraging and supporting entrepreneurial activities among its faculty members such as the development of income generating products, consulting, business linkages, and interdisciplinary partnerships. Other literature indicated that due to globalisation, the traditional mainly disciplinary knowledge is now being supplemented by trans-

disciplinary knowledge, knowledge produced within various applied contexts and knowledge that is heterogeneous and organizationally diverse. The implication for nanotechnology is that the conduct of research and training in the field of nanotechnology will not remain within the confines of the universities. Faculties in the University cannot remain highly rigidified; instead faculty members will be given opportunities to interact with their academic colleagues and knowledge producers in a range of other institutions.

Secondly, the study has argued that the interplay of global and national pressures has led to the need for the university involvement in the area of nanotechnology. The South African government has created an enabling environment that supports nanotechnology activities in the University, such as the establishment of a dedicated fund to support the creation of interdisciplinary and inter-institutional post graduate nanoscience and nanotechnology programmes in the university. Presently, several South African Universities such as the University of Cape Town, the University of the Western Cape, the University of Pretoria, University of Kwazulu Natal, the University of the Witwatersrand etc. are actively participating in the national initiative.

Thirdly, the study has shown that the need for nanotechnology as a result of globalisation has put pressure on the South African government to come up with a national nanotechnology strategy, which aim at accelerating research and development, innovation, education, training and curriculum development and improving the life of all South Africans.

There are various interesting theoretical insights that also emanated from the study. The study has shown that Nanotechnology research at the University of the Witwatersrand is more multidisciplinary in nature than interdisciplinary. For instance, a variety of Science and Engineering disciplines such as the Faculties of Built and Engineering, Science and Health Science are involved in Nanotechnology activities with little or no interaction among these Faculties.

With regards to the experiences of the University in providing education and training in the area of Nanotechnology, the study has revealed that at the moment only one Faculty, the Faculty of Engineering, School of Chemical and Metallurgical Engineering has integrated nanotechnology into its Chemical Engineering curriculum. The study showed that the School of Chemical Engineering has so far provided training on Nanotechnology to its third and fourth year Chemical Engineering students. In addition, it has also organised numerous short courses on nanotechnology drawing participants from local and international universities, industries and research institutes.

In the area of research, the study has shown that Wits has been involved in several nanotechnology research activities. It has several local and international publication and conference presentations to its credits. In addition, it provided smooth environment for multidisciplinary research, with students from different academic background researching in nanotechnology. The study also showed that Wits is involved in research collaboration with other university and industries in the area of Nanotechnology.. However, the study argued that Wits can play more effective role in Nanotechnology if it involves more of its academics in nanotechnology related activities, integrates nanotechnology into its curriculum and increases research collaboration with other knowledge producers such as industries, research councils and other universities. This is because evidence from literature shows that nanotechnology is interdisciplinary in nature and benefits from knowledge producers from different institutions (Martinez-Fernandez and Leevers, 2004; Roco, 2002; Singer et al. 2005; Chang 2002).

7.2. Recommendation for further studies

The study recommends that for Nanotechnology to contribute to South African economic development, the University of the Witwatersrand need to help in this regard, by playing a more proactive role such as involving adequate number of academics in developing human resource capacity in Nanotechnology. Moreover, interaction among faculty members across disciplinary boundaries is also essential and should be facilitated and promoted actively. One of the ways to make this possible is for Wits to encourage and support nanotechnology interdisciplinary programs of studies, research programs and curricula.

In addition, apart from basic research the University should pay attention to more application based research in Nanotechnology. The government and private sectors can help encourage this kind of research by providing funds to the University.

Furthermore, Wits should be more research collaboration between Wits and other knowledge producers such as those in the industries, government, research institutes, civil society etc, since Wits has limited linkages with these institutions. The collaboration should also improve the teaching, learning and research role of the university.

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Appendix

UNIVERSITY OF THE WITWATERSRAND

Interview guide

Investigating the role of the university in the field of Nanotechnology.

Section 1

Sample Demographic Breakdown

Gender _____ Race _____ Age _____

Department _____

Position held _____ Number of years in service _____

Other _____

Section 2

University Academics

1. From your point of view what is nanotechnology?

2. What is the general conception of nanotechnology in the University?

3. Why are you involved in nanotechnology?

4. How long have you been involved in nanotechnology?

5. What is your vision regarding the changes that nanotechnology will bring to the South African society?

6. What role can nanotechnology play in the growth of South Africa within the global economy?

7. How would you describe the role that you play in the field of nanotechnology? What role has the university played and should play in nanotechnology?

8. What do you think of the potential of South African Engineering or Science graduates, in terms of employment needs?

9. Do you see a need to educate and train engineering or science students in the field of nanotechnology?

10. Exactly what type of programs have you developed at the university to teach nanotechnology to students?

11. What research on nanotechnology is going on in the university? Are there any specific funding opportunities? Give details.

12. What kind of collaboration do you have with other universities, industries research institutes, and government department? Please describe.

13. In your view, what is the university approach to research and training in nanotechnology? Entrepreneurial, commercial or purely academic? What are the benefits and the downside of this approach?.

14. By necessity, government plays a role in many aspects of our lives. In your opinion, what role does the South African government play in the development of nanotechnology? How does this role relate to the universities? How can this be improved?

15. What is your overall feeling about the South African National Nanotechnology Strategy? Is this reflected in your work at the University? How?