

Exploring Research and Innovation in Engineering Education: The Case of a South African University

Kehdinga George Fomunyam



Abstract: *There has been increase in the global population and this comes with the need to have a rethink to sustain economic growth. Research and innovation is an identified avenue which encompasses several fields of science and technology, such as engineering, social sciences, humanities, and natural sciences. This study explored research and innovation in engineering education using a South African University as a case study. University of Pretoria was chosen for the case study because this institution ranks highly among others in engineering discipline. Findings from the study reveal that in a world shaped by a high degree of complexity, fluidity and uncertainty, there is a dire need for research and innovation.. To explore Research and innovation in engineering education at this university, data was gathered using the right keywords, and a total of 57 thesis and dissertation were downloaded and categorized for this study. The categorization was done using keywords and concepts in the research topics to ensure uniformity. From the categorization, seven themes were drawn which are project management, intelligence and leadership, emerging technologies in pedagogy, engineering systems and product design, heat and energy, innovation and knowledge, entrepreneurship and career. The study concludes that increasing investment in research innovation remains a vital option to ensure growth and economic increase. Thus, creating a conducive atmosphere for the conduct of the discipline and increasing funding for research and development along that line is paramount.*

Keywords: *research, innovation, engineering, engineering education, South Africa, case study*

I. INTRODUCTION

According to the United Nations (2018), there is inadequacy in basic infrastructures like electricity, housing, roads, information and communication technologies in developing countries. Over 800million people in the globe can not access clean water, and about 1billion cannot access communication devices such as internet and phones. About 2.5billion people are challenged by non-sanitized environments which have been reported to be predominant among developing nations. With rapid increase in population, there is a therefore a need to have a rethink to sustain economic growth and better life for people which can only be made possible by research and innovation. Research and innovation according to Gaillard (2008) encompasses several fields of science and technology, such as engineering, social sciences, humanities, and natural sciences.

Manuscript received on April 02, 2020.

Revised Manuscript received on April 15, 2020.

Manuscript published on May 30, 2020.

Dr. Kehdinga George Formunyam, Teaching and Learning Development Center, Mangosuthu University of Technology, South Africa.

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This implies that research and innovation in engineering is made possible with other disciplines as mentioned above. Innovation is a broad concept that takes different form. The major importance of innovation is to ensure improved performance. Innovation is defined as the use of a novel or meaningfully improved creation that is predicated on resources, commitment, and an advanced structure within an organization (Badran 2007; OECD, 2005; Utterback 2002). It has been revealed that South African institutions lack well defined business structures for creating innovations despite their creative abilities, knowledge, skills and drive to produce original ideas. This was attributed to an overload of work, improper constitution of innovative behavior and unavailability of financial support (Jakovljevic 2013; Christensen 1997; Armstrong 2014). Also, limited number of African universities have updated curricula or use teaching methods that encourage research and innovation. In most African universities, the goal is still to teach and give out degrees, whereas much of the world is experimenting with new models that can ensure transformation of the economies of the regions in which they are located (Trencher *et al.*, 2014) This is a gap in the entire framework of engineering education which has limited the growth of the discipline in Africa as a region and specifically to South Africa in the context of this study. This has consequentially resulted to poor economic development as early works of Adam Smith in 1776 typified the nexus between innovation and economic development. Also, as a result of changes in the general scheme of events, there is a need to have new approaches and skills to issues and this needs to be matched with the right ways of learning (Adams, Kaczmarczyk, Picton, & Demian, 2010; Graham & Crawley, 2010) It is important to note that innovation cannot be possible without research and they go hand in hand. Research helps in furthering the discoveries made in innovation. The persistent tendency to have a new dimension to issues can only be made possible through the apparatus of research. Innovation and research is important in causing a change in the South Africa, and the National Industrial Policy Framework (NIPF) revealed that the country has poor performance in nontraditional tradable goods and services and there is a need to encourage research and innovation in order to increase investments. South Africa has been reputed to be the center of engineering education in Africa as a result of developed infrastructures that are important for the conduct of engineering education as a discipline. Having a look at research and innovation in engineering education will proffer an insight into what the future holds for the profession. Consequently, this research work will conceptualize research and innovation, take a critical look at innovation and research in engineering education, analyze its challenges and obstacles, and explore research and innovation in a South African University.

II. RESEARCH AND INNOVATION: REVIEW OF LITERATURE

As it has been revealed before that research and innovation goes hand in hand, the two concepts will be conceptualized to gain more understanding of it in the light of this research work. Etymologically, Amidon, 2003 states that innovation is derived from the word *Innovare*, a latin word which means to make new. This definition showcases existence before and a drive to make it better. Innovation is a broad term used in many disciplines and it is described as new way of proffering solution to a problem and doing things. Doyle (2002) was of the opinion that innovation involve bringing an idea to a use on a commercial level. Tidd, Bessant and Pavitt (2002) argued that innovation is all about change. Having a change in processes, good and services and the way it was created or delivered. O'Regan, Ghobadian, & Sims, (2006) were of the opinion that innovation is a new approach to identifying what the needs of customers are. Jobber (2001) gave another perspective when he maintained that innovation occur when a new idea is commercialized by taking it to the market. Kings and Anderson (2002) argued that innovation include several scientific, organizational, technological, financial and commercial activities and it was delineated into three phases which are the problem identification and idea generation, gathering support, idea implementation (Utterback and Abenathy, 1975). Simonton (2003) cited by Shavinina (2003) shed more light on innovation and it was revealed that innovation stimulates exceptional creativity across the life span. This definition highlights the foundational process for encouraging innovation which starts from the experiences in life, family makeup and background, education and professional training etc.

Other authors revealed that innovation might not be born out of creativity and stressful circumstances which can cause people to find better alternatives to doing things. Circumstances such as lack, fear, frustration, depression, poverty, threat can fuel the desire to innovate (Herzen and Vail, 2003). Innovation is not restricted to a particular domain; it is a multi-disciplinary transfer of knowledge (Shavinina 2003). It does not stand alone and it has an underlying factor which is creativity. Creativity is a precursor for innovation and it encourages growth and strength in an economy (Monica RR, 2009). According to Camisón C, Forés B (2010), innovation is the conversion of new or existing knowledge to value which can be made manifest in goods or services for the use of people, groups or society. It stems from knowledge acquired over time. It is vital in developed and developing countries for proffering solution to various challenges that are predominant there. Innovation according to Wolpert (2002) was seen as leveraging on new business opportunities, new technologies and causing a change in the conduct of business. Barton, Schlemer, and Vanasupa (2012) opined further on innovation in engineering education by categorizing it into three which are problem solving, process improvement and transformation.

Various authors have defined what innovation is and from the definitions above, what stands innovation out is novelty. With various changes taking place recently, to remain relevant in the grand scheme of events, it is important to consider innovation which brings newness into ventures. Moreso, innovation can also rely on creativity as revealed

by one of the authors. A persistent desire to have an overhaul fuels creativity in people. The need to have a rethink to business processes, production of goods and services will promote creativity in individuals.

With knowledge not static, new knowledge brings new approach to various processes and adopting it will cause a transformation along engineering education lines. creativity gives strength to innovation which has the capacity to cause growth and increase in the economy. With things rapidly changing factoring in the technologies that are emerging at this time, innovation will come at a fast pace and there will be differences in economies as a result of their adoption or non-adoption of these innovation which has the capacity for economic development (Adam Smith, 1776). This has created a divide between countries of the world just like we have a dichotomy between the global North and the Global South. One, characterized by advanced technologies which improves daily interaction and business processes and the other characterized by dependence on the primary stage of production, widespread poverty and backwardness. It is therefore important that innovation in engineering education be intensified upon in South Africa to improve the economy and the production processes.

As stated by the Australian National Audit Office (2009), innovation is basically the process of creating and implementing new, products, processes, services and systems of delivery which has the ability to make giant improvement in effectiveness, efficiency, and standard results obtainable.

III. THE IMPERATIVE OF RESEARCH AND INNOVATION IN ENGINEERING EDUCATION

It is noteworthy to bear in mind that innovation and adequate research is key in engineering education and they are inseparable from it (F. J. Garcia-Penalvo *et al*, 2014). With the need to ease difficult processes and to ensure that there are better approaches to issues, research and innovation is important. Taking a look at history, over time, man has evolved from simple primitive being to a high level of sophistication. The move from the use of simple tools to make ends meet has now developed into large technologies which has shaped the existence of men. Therefore, engineering education, research and innovation are inseparable and they maintain a symbiotic relationship.

In a world shaped by a high degree of complexity, fluidity and uncertainty (R Bolstad *et al*, 2012) there is a dire need for research and innovation. It is important to acknowledge that times are changing and with the changes are new issues to deal with. Hence, the dire need to encourage research and innovation in engineering education. The world is on a fast pace and what is needed is a propensity to move with it in order to avoid being left alone. As there are changes in the world, it has become more complex than before and there are emerging issues to deal with generally and in engineering education.

Also, structures and methodologies of the educational system recently, are inadequate to aid the learning needs of today's society. With the new changes as highlighted above, there will be the need to have new approaches to the educational dimension of engineering education.

With massive changes taking place in the social, economic, environmental and technological world, which has necessitated the need for increasing amount of human knowledge to deal with this changes.

There are now complex challenges evolving as a result of changes in the social, economic, environmental and technical sphere and some of these challenges have been tagged impish problems because they are massively complex, value driven, and uncertain (Frame, 2008). So there is a vital need for students and lecturers to develop the capability to combat these problems from an engineering standpoint.

The future engineers are meant to be high qualified in an attempt to remain relevant and in the future as revealed by World Economic Forum, some of the top skills that will be relevant include creativity and innovation. This necessitates the need for research and innovation in engineering education. To become credible leaders, research and innovation is important. This is in line with the findings of IBM which maintained that around 1500 CEOs noted that creativity is important in leadership. There is also a nexus between research, innovation and the capability to solve problems. To deal with the complex problems that will come in the future, there is a need for engineers to learn new ways of approaching these problems (Garcia-Penalvo et al, 2012; Garcia-Penalvo et al, 2014; Colomo-Palacios et al, 2012).

IV. METHODOLOGY

This paper utilizes a case study approach to explore research and innovation in engineering education. According to Abercrombie, Hill, & Turner (1984), a case study is simply a critical outlook or an examination of a distinct instance of a class of phenomena, like an activity, an individual, a group, a community, or an event (Shepard & Greene, 2003). As a methodology, case study can be utilized to motivate valid findings resulting from the analysis of multiple cases, or a single case, such as a town, an institution, a body, an association etc. For the purpose of this study, a University in South Africa is the subject of focus and University of Pretoria, South Africa was chosen. This was because the institution ranks highly among other universities in South Africa in engineering disciplines. To provide a basis for the research, a systematic literature search was carried out to locate and aggregate researches along engineering education lines in a South African University. To consider research in engineering education in the institution of study, the database for thesis and dissertation in the institution was the source of data.

1. Inclusion/exclusion criteria

Two inclusion criteria was considered to screen for relevant studies along engineering education lines. they are (1) thesis and dissertations published between 2010 and 2018 and (2) has the necessary keywords that are related to the concepts of the study and they are (a) research (b) innovation (c) engineering education (d) South Africa (e) engineering

2. Data screening and exclusion

For this approach, a total of 57 thesis and dissertation published between 2010 and 2018 were considered. They include thesis and dissertation from the repository of University of Pretoria. From the thesis and dissertation downloaded, they were categorized using concepts from the

topics and from the categorization, Seven themes emerged which were analyzed to lend credence to the topic under consideration.

V. FINDINGS AND DISCUSSION

From the categorization of the thesis and dissertation, seven themes emerged which will be analyzed to explore research and innovation in engineering education.

1. Project Management

In University of Pretoria, South Africa, some of the major research and innovation focuses on project management in engineering education. There are various definitions of projects. Cleland & Kerzner(1985) defines a project as a composite of nonhuman and human resources, temporarily organised to achieve a predetermined purpose. PMBOK (2008) defines a project as a temporary venture initiated to fashion a unique service, product, or result. A project in the last century was defined as a developed archetype of buildings, construction, manufacturing. The definition has changed recently and a project is any type of activity which has a lifespan. Projects are vital in engineering education and the entire process from initiation, preparation, planning etc to delivery must be carefully factored in before venturing into any type of engineering project. The need to ensure that projects are delivered seamlessly is important for having research and innovation in engineering education in University of Pretoria, South Africa. Project management is a multi-disciplinary field that has in it various features such as scheduling, finance and costs, legal dimension, procurement, risk, quality management etc. research and innovation is important to ensure that projects are delivered appropriately and to encourage sustainability. With more than 30years of education and training in project management, the University of Pretoria has maintained reputation for quality delivery and leadership in project management in Africa. Project management is an ancient phenomenon and a typical example is the building of the pyramids in Egypt as at 2000BC. But in recent time, project management began in the 1950s as a specialized research area. Taking a reference from history, Maylor (2005) emphasized three stages of project management. Before the 1950s, project management had not gained recognition, but in the 1950s, specific techniques and tools were created to aid management of difficult projects and from 1990s onwards, the changing environment in which projects take place was put into consideration.

With the emerging trends in globalization, managing a project now viewed as an international affair with a lot of risk and uncertainty. White & Fortune (2002) posits that project management is taking a new leaf and its being developed and accepted as a discipline for professional expertise, and as thematic area for academic discourse. However, it remains a highly problematic venture. Howes & Tah (2003) argue that due to the risks and uncertainties associated with project management, it is pertinent that Project managers understand the factors that can impinge upon the project environment.

2. Intelligence and Leadership

Graduates of engineering education requires many skills and knowledge to perform within the academic environment and outside the four walls of the institution. Essential amongst this are interpersonal skills, teamwork, motivation etc. education is all encompassing and should not only develop technical skills in students, there is a need for skills set that will make them competitive and successful on their job and some of this skills include intelligence (Goleman D, 1999). With intelligence being a very wide concept, it has been a major research focus for university of Pretoria and some researches have been done on it. With various dearth in the engineering curriculum in south Africa and inadequacy of skills necessary to translate into good fortunes for the country, it is worthwhile to ensure that research and innovation focuses on intelligence and leadership at university of Pretoria, south Africa. There is a dire need for more skills with the lessons from engineering education and to create a balance between theory and practice. Intelligence and leadership are skills that are taught and learnt and along leadership lines in engineering education, there must be intelligence. Intelligence is broad and multifaceted and some of the aspect of intelligence researched on in university of Pretoria include contextual intelligence, competitive intelligence, emotional intelligence amongst others.

Emerging technologies in pedagogy

Another area of research and innovation embraced by university of Pretoria is emerging technologies in learning. With the various changes taking place along the digital divide recently, there has been emergence of various approaches to learning which emerged as research and innovation focus at university of Pretoria. Emerging technologies in pedagogy tries to overhaul educational elements such as, the need to have a teacher physically present, buying of expensive paper textbooks, and the demand for one to be physically present in a classroom before learning can take place. These emerging educational technologies is important for teaching and learning as it tries to ensure that the process is engaging, relevant, and efficiently carried out. With these emerging technologies, students will be more attracted to the and the universities will enroll them. There is hope for education now and in the future as there is an increasingly complex emergence of technological innovations. Therefore, educators need to critically focus on building relevant educational experiences which can only be made possible by research and innovation. Only then can they select the right technologies be developed for the right target audience to bring out the best way to facilitate learning. Some of the technologies researched into include

3. Entrepreneurship and Career in Engineering Education

Developing economies like that of South Africa most often face several economic development challenge, and the correlation between entrepreneurship and economic growth in economies like this is most often documented. Wang C.L (2008) argues that the crux of entrepreneurship is creating wealth. Entrepreneurial ventures drive change and growth in every economy, and this entrepreneurial attitude continuously fuels this growth. Due to the understanding of this marriage between entrepreneurship and economic growth, West *et al* (2008) postulates that entrepreneurial development is acknowledged as a solution to economic

transformation, improving the prospects for innovation that is self-generated, and producing qualitative advancements to the social and economic fabric of an area. Small enterprise development has been identified by the South African state as a vital panacea for economic growth and job creation (Sasix, 2009). Recently, there has been a record of low entrepreneurship activities in South Africa as compared to the progress recorded by other developing nations. For one, entrepreneurs in South Africa contribute about 35% of the nation's Gross Domestic Product (GDP), while other developing nations such as Brazil and India contribute as high as 60% (Maas & Herrington, 2007). Hence, the need to have research and innovation in engineering education in South Africa.

4. Innovation and Knowledge

The continuous drive to have updates and outcome that typifies today's society in general and the engineering discipline in particular has prompted accredited engineering programmes to repeatedly call for an overhaul in the pedagogical approach to engineering education (Crawley et al., 2007; Percy & Cramer, 2011). National agencies (NAS, 2007; HSV, 2010). There have been attempt by scholars to emphasize research and innovation especially among the workforce. Major features of future engineers include innovativeness and advanced technological fluency (NAE, 2005). Having researches in innovation and knowledge as exemplified by University of Pretoria will ensure that engineering education graduates are well taught and they can demonstrate practice of what they were taught by bringing out new approaches to issues.

Findings from the study revealed that there is inadequacy in basic infrastructures like electricity, roads, water, housing, and communication technologies in developing countries. Over 800million people in the globe can not access clean water, and about 1billion cannot access communication devices such as internet and phones. About 2.5billion people are challenged by non-sanitized environments which have been reported to be predominant among developing nations (United Nations, 2018). These statistics are staggering and they lend credence to need to intensify effort on research and innovation especially in developing countries which South Africa is a part of. It has been revealed that there are inadequate business designs and structures for creating innovations in South African learning institutions despite the creative abilities, knowledge, skills and drive to produce original ideas. From the thesis and dissertation downloaded for this study, research and innovation in University of Pretoria was categorized into project management, intelligence and leadership, emerging technologies in pedagogy, engineering systems and product design, heat and energy, innovation and knowledge.

VI. CONCLUSION AND RECOMMENDATION

Many scholars are of the opinion that research and engineering innovation and adoption which can be made possible by intensifying effort and increasing investment in research and innovation remains a vital option to ensure growth and economic increase in nations especially developing countries which South Africa is a part of.

It is therefore important that the government of the developing countries look towards research and innovation in engineering education and increase support for it. This can be done by creating conducive atmosphere for the conduct of the discipline and by increasing funding for research and development along that line. Premium should also be placed on universities and industries and ensuring that there is a synergy between the two. This will ensure that adequate rapport is created aimed at solving the complex challenges in this domains. Research and innovation has been a factor that ensure rapid growth in developed countries as clearly seen by the various developmental strides made there. The role of the university in research and innovation cannot be trivialized and they are the necessary for production of knowledge that culminates in development and better standards of living. Therefore, more support and polices is needed to ensure that research and innovation thrive well in the universities. With more focus on research and innovation, there will be tremendous economic development recorded in South Africa as a result of relevant economic institutions and the enactment of vital policies that ensure that research and innovation thrive well.

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