Engineering Students' Innovation Competence: A Comparative Analysis of Nigeria and South Africa

Omoseni Adepoju (✉), Nnamdi Nwulu
University of Johannesburg, Johannesburg, South Africa
adepojuomoseni@gmail.com

Abstract—The main purpose of this study is to assess the role of tertiary institutions in impacting innovation competence among graduating students in the engineering discipline. To achieve this aim, two research questions were investigated: First, we examine if the graduating students possess some key innovative competence qualities innovative competence which include qualities such as creativity, leadership, self-efficacy, energy and risk propensity. Secondly, we investigate the key elements of tertiary institutions that impact innovative competence among the graduating students. A structured questionnaire was administered to graduating engineering students at the Federal University of Technology Akure, Nigeria and University of Johannesburg, South Africa during the 2019/2020 academic session and their responses were compared. Results indicate that students generally had a high assessment of their innovation competence and attributed some of this competence to their institutions learning environment.

Keywords—Innovation, Competence, Tertiary institutions, Engineering

1   Introduction

Innovation competence can be defined as the ability to conceptualize and execute ingenious ideas that have practical and tangible impact [1]. These ingenious ideas can either take the form of a product or service [1]. There is an attitude and skill set required to successfully conceptualize and implement innovative ideas consisting of precise knowledge, resilience, self-motivation and creativity [2]. This is because innovation is a complex endeavor and the innovation process involves uncertainty with no guarantee of success [13].

Of crucial importance from an engineering pedagogy perspective is the learning environment where innovation competence is nurtured. It is imperative that learning environments are deliberately designed to foster this competence.

A good way to gauge the effectiveness of learning environments in fostering innovation competence is to evaluate students' perceptions of their learning environments. Prior research has shown that there is direct correlation between students' perception of their learning environment, learning outcomes and innovation competence [4]. If the aim is to design pedagogically sound approaches that foster innovation competence in the engineering context, teachers have to obtain feedback via students' self-assessment

of their own innovation competence. Furthermore, it is also imperative to obtain students assessments of their learning environment and if it fosters innovation competence. There has thus been a commensurate interest in understanding how the learning environment contributes to developing innovation competence [3] from the literature. A recent work that investigates these concepts is [5] where students' assessment of their own competence and their learning environment was performed. This was done via the distribution of 130 questionnaires to build environment students seeking to measure their opinion on whether their institution's curricula had succeeded in fostering innovation competence. This work builds on the approach adopted in [5] and performs a comparative analysis of students' self-assessment of their innovation competence and that of their learning environments in Nigeria and South Africa. The choice of Nigeria and South Africa is motivated by the fact that both nations account for approximately 50% of sub-Saharan Africa's gross domestic product [6] and South Africa is regarded as the most innovative country on the African continent [7].

The main purpose of this study is therefore to assess the role of tertiary institutions in impacting innovative skills among graduating students in the Engineering field, using both Nigeria and South Africa as a case study. The specific objectives are to:

a) Examine engineering graduating students' self-assessments of their innovative competence
b) Investigate the key elements of tertiary institutions learning environments that impart innovative competence among the graduating students.

The rest of this paper comprises of the conceptual framework for innovation competence and innovation learning environments, research methodology, results and discussions of findings respectively. In addition, the paper was concluded in line with findings and recommendations were made.

2 Conceptual Framework

Within the engineering education domain, the framework for assessing innovation competence amongst tertiary institutions utilizes six key components [2], [5]. The first key component is Creativity. Creativity is the first attribute required after the identification of a complex problem [2], [8]. The creative problem solver (in this case a student) has to keep an open mind about the vast possibilities of variables and/or parameters that affect the problem and possible solutions. Furthermore, the creative problem solver has to be able to draw connections and causal relationships between various scenarios in the problem domain [10],[11]. Creativity involves questioning assumptions, challenging stereotypes and leveraging on the power of imagination [8]. The second component of innovation competence is leadership. Leadership is the ability to obtain the wholehearted buy in of all partners and team members in order to actualize the envisaged solution to the problem at hand [2]. The third component of innovation competence is referred to as creative self-efficacy, which simply put is the degree of self-confidence a student has in their problem-solving ability. This component is linked to the domain specific knowledge the student has. The fourth component is termed energy, which refers to the ability to doggedly pursue an innovative solution to hitherto identified

problems [2]. This component is key as it describes the ability to surmount challenges/obstacles on the path to obtaining solutions. The fifth component is risk propensity. Risk propensity is one of the key traits of innovators as they are able to ignore the uncertainty within the problem domain and find solutions. The sixth component is termed ambiguous problem solving and relates to the ability of students to persevere and find solutions to ill-defined or ambiguous problems. The authors believe that elements of this component have been captured in the prior five components and thus will be excluded in this paper. These are also the components detailed in [2].

Concerning learning environments, prior research has shown that teachers have long sought to foster and/or develop students' innovation competence through teaching [5]. The learning environment under which teaching is done therefore deserves scrutiny. We therefore investigate the effect of five learning environment factors on the innovation competence of students. The five factors are lecturers' teaching method, modernized learning techniques, institutional infrastructural capacity, university-industry collaboration and the level of institutional funding. The choice of the learning environment factors is motivated by the analysis of relevant literature [13] which posit that these are key learning environment factors. The hypothesis constructed and investigated in light of the five factors are:

Hypothesis 1: The lecturers' teaching method significantly impacted the acquisition of innovative competence among the graduating students in Engineering.

Hypothesis 2: Modernized learning techniques significantly impacted the acquisition of innovative competence among graduating students in Engineering.

Hypothesis 3: Institutional infrastructural capacity significantly impacted the acquisition of innovative competence among graduating students in Engineering.

Hypothesis 4: University – Industry Collaboration in the institution significantly impacted the acquisition of innovative competence among graduating students in Engineering.

Hypothesis 5: Level of research funding in the institution significantly influenced the acquisition of innovation competence among graduating students.

3 Methods

The population of the study comprised of final year engineering students at the University of Johannesburg (UJ) in South Africa and Federal University of Technology (FUTA) in Nigeria. A total number of 530 (UJ =210 + FUTA =293) were derived from the 2019/2020 academic session. The sample size (n) was calculated using Taro Yamane formula [12].

$$n = N \qquad\qquad\qquad 1+N\,(e)^{2}$$

where n = sample size, N = population size, and e = Margin of error (MoE), e = 0.05.

This calculation gives a sample of 138 (UJ) and 169 (FUTA). A structure questionnaire was used to collect data. The questionnaires were crafted in line with the research objectives of the study. i.e. to obtain students assessment of their own innovation competence and secondly to investigate the key elements of tertiary institutions learning environments that impact innovative competence among graduating students. This methodology was adopted in line with prior related works on the subject matter [2], [5].

A five-point Likert response scale was used with responses Strongly Disagree, Disagree, Undecided, Agree and Strongly Agree for questions that correspond to the five components of innovation competence. In order to answer research objective 1, the obtained student responses were analysed using calculated mean and standard deviation values. For research objective two, simple liner regression was performed which sought to find out what factors in the institutions learning environment influenced student's innovation competence.

Questionnaire Response Rate

Out of 138 questionnaires distributed to UJ, 90 were retrieved and out of 169 distributed to FUTA, 105 were retrieved. This gives a response rate of 65% and 62% for UJ and FUTA respectively. This response rate was considered adequate and consistent with [9] who suggests that any response rate above 50% is generally representative for a descriptive study. Therefore, the sample was considered adequate for the researcher to draw a conclusion and generalize research findings. The demographic characteristics of the respondents is given in Table 1.

Table 1. Demographic Characteristics of the Students

	UJ		FUTA	
	Frequency	*Percentage (%)*	*Frequency*	*Percentage (%)*
Gender				
Male	73	81.1	90	85.7
Female	17	18.9	15	14.7
Total	90	100	105	100
Age				
Below 15				
16 – 20	17	18.9	21	20.0
21 – 25	54	60.0	66	62.9
26 – 30	19	21.1	18	17.1
above 30	-	-	-	-
Total	90	100	105	100
Educational Background				
Engineering	90	100	105	100
Total	90	100	105	100
Institution		UJ		FUTA

Source: Research Data (2019)

4   Results

Results obtained for research objective 1 are shown in Table 2 and Figure 1 respectively. Table 2 gives the mean scores of UJ and FUTA students' innovation self-assessments corresponding to the five innovation competence components. Figure 1 shows the overall mean for each of the five components for students of both institutions.

Table 2. Assessment of Level of Innovative Skills among graduating students in UJ and FUTA

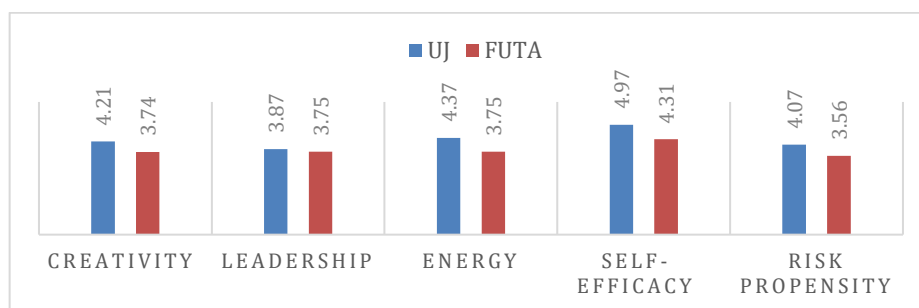|	Mean	
Creativity	*UJ*	*FUTA*
My courses involved lot of creative activities	4.18	3.632
My course of study has facilitated my power of imagination	3.91	3.662
My course of study has driven me to generate ideas and solutions to problems relating to my field	4.26	3.809
My course involved real life practical's in school which aided my creative thinking	4.24	3.824
I have learnt how to make complex choices and decisions in the course of my study	4.38	3.559
I have learnt to be inquisitive and ask questions to clarify various doubts and broaden my knowledge in the course of my study	4.24	3.809
My course involved real life practical's in school which aided my creative thinking (from the environment)	4.29	3.882
LEADERSHIP		
Students are encouraged to take leadership roles during my study	3.97	4.029
Distribution into class groups gives me a chance to take a leading role (in form of team/group leader)	3.71	4.103
My course entails series of seminars and presentations which have improved my communication skills with lecturers and colleagues	3.68	3.206
My course avails me the opportunity to inspire my colleagues through sharing knowledge and tutorials	4.03	3.632
My course gave me the freedom to take decisions independently to generate results/ solutions	3.97	3.765
ENERGY		
In my course, excellence is rewarded based on hard work	4.18	3.265
My courses demand much energy to get results	4.26	3.941
I have learnt to exert energy to get good grades in my courses	4.29	3.912
I spent long hours and effort to come up with innovation	4.38	3.956
My course has built up energy required to get to the peak in my profession	4.03	3.691
SELF- EFFICACY		
I work independently to generate results in the course of my study	4.00	3.588
I have designed something in the course of my study and I feel proud about it	4.21	2.956
My course gave me freedom to express my own ideas	4.09	3.912
Due to my course of study, I have developed self-confidence over the years	4.06	3.721
I am not afraid to face any challenge in my pursuit of my profession	4.15	3.779
The school have brought me up to always think for myself	3.82	3.588
RISK PROPENSITY		
My course involves a high level of risk taking	4.03	3.632
My course has increased my risk taking and my ability to come up with solutions to problems	4.44	3.309
My Experience in my course of study has given me the confidence that I can solve any problem	4.00	3.368
I take decisions based on my drive to achieve regardless of future consequences	3.74	3.574
I take risks on an activity that might enhance my chances of getting good grades in school.	4.15	3.926

Fig. 1. Assessment of Level of Innovative Skills among graduating students in UJ and FUTA

Table 3 below shows a simple regression analysis of the impact of five learning environment factors on the innovation competence of students. The five factors are lecturers' teaching method, modernized learning techniques, institutions infrastructural capacity, university-industrial collaboration and the level of institutions funding corresponding to five hypotheses. Results in Table 4 show the following metrics: R, R^2, F-ratio and the significance (P value).

Table 3. Key elements of tertiary institutions learning environments that impact innovative competence among graduating students

	HO1		HO2		HO3		HO4		HO5	
	UJ	*FUTA*	*UJ*	*FUTA*	*UJ*	*FUTA*	*UJ*	*FUTA*	*UJ*	*FUTA*
R	0.625	0.701	0.858	0.901	0.701	0.858	0.869	0.855	0.865	0.990
R^2	0.390	0.492	0.737	0.811	0.492	0.737	0.755	0.731	0.732	0.979
F/ratio	74.2	69.2	34.2	24.3	53.63	34.25	30.33	14.13	12.66	40.79
P	0.005	0.15	0.002	0.653	0.148	0.002	0.004	0.163	0.210	0.00

5   Discussion

Research Objective 1: Self-assessment of innovative competence among graduating students in UJ and FUTA

In Table 3 a comparative assessment of the level of innovation skills which was distilled into 5- stages- creativity, leadership, energy, self -efficacy and risk propensity was conducted among the students of UJ and FUTA. The results show that UJ students assess themselves as having higher levels of innovation competence than FUTA students have. UJ students typically scored themselves high on creativity, self-efficacy and energy. They scored themselves much lower on leadership and risk propensity. FUTA students on the other hand rated self-efficacy as their most innovative trait with risk propensity their lowest rated trait. Creativity, energy and leadership were rated almost equally. The results obtained from UJ students aligns with what is obtainable in the literature [2], [5] where students scored themselves highly on creativity, self-efficacy and energy. It was postulated in these works that students who score high scores in these components are in line to be innovators outside the University. This perhaps explains why South Africa is the most innovative country on the African continent.

However, the UJ results are an indication that students need to take the initiative in problem solving and risk taking. Deliberate steps have to be taken where students take the initiative in solving problems whilst doing so out of their comfort zones. This can be via increased incorporation of Project Based Learning (PBL) subjects/modules into the UJ curricula, as this will increase the students' problem-solving capacity. FUTA students assessed themselves highly for self-efficacy, which suggests a heathy dose of problem-solving confidence. However, in light of the lower creativity, energy and leadership scores, it is advised that courses be designed with creative and practical activities, which will enhance the students' power of imagination and creative ability. Students should also be encouraged to take the driving seat in innovative activities. A key method to achieve this should be the increased inclusion of ill-defined problem solving in the FUTA curricula, as the lack of clear-cut solution methodology (a key tenet of ill-defined problem solving) will foster students' creative capacity.

Research Objective 2: Investigate the key elements of tertiary institutions learning environments that impact innovative competence among graduating students.

In order to investigate this research objective, five hypotheses were constructed and the responses of the students sought. From Table 4 hypothesis 1, UJ students record a significance level ($p = 0.005$) which indicates that the model is significant at $p < 0.005$. This implies that in the opinion of the students, lecturers' teaching method significantly influence the acquisition of innovative competence. Analysis of FUTA student's response on the other hand yielded a significance level ($p = 0.15$) which indicates that the lecturers' teaching method does not significantly influence the acquisition of innovative competence. Similar analysis shows that UJ students posit that modern teaching methods and university-industry collaboration also impact influence their acquisition of innovation competence. UJ students posit that the level of institutional funding and infrastructural capacity do not influence their learning environment for innovative competence whilst these are the factors that FUTA students posit influence theirs. This can be explained by the fact that UJ has better infrastructural capacity and funding that FUTA and UJ students probably accept it as a given. FUTA students on the other hand believe that it has a significant effect on their learning experience and subsequently on their innovative competence.

6   Conclusion

This article considered the self-assessment of engineering students' innovation competence and the effect learning environments of tertiary institutions had on this competence. Final year engineering students at the University of Johannesburg and the Federal University of Technology Akure in South Africa and Nigeria respectively were the study respondents. UJ students typically scored themselves high on creativity, self-efficacy and energy. They scored themselves much lower on leadership and risk propensity. FUTA students on the other hand rated self-efficacy as their most innovative trait with risk propensity their lowest rated trait. Creativity, energy and leadership were rated almost equally. The students also identified the learning environment attributes in their institutions that fostered their innovative competence. The results indicate that there is

still need for deliberate attempts to increase the innovative capacity of students in UJ and FUTA. A key recommendation is that more PBL and ill-defined problem solving should be introduced into the engineering curricula at UJ and FUTA respectively. Future research work should assess innovation competence using a larger sample size, across various disciplines and various education levels.

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8   Authors

Omoseni Adepoju is a Post-Doctoral Research Fellow, Faculty of Engineering and Built Environment, University of Johannesburg, RSA. Email: adepojuomoseni@ gmail.com

Nnamdi Nwulu is an Associate Professor, Faculty of Engineering and Built Environment, University of Johannesburg, RSA.