International Journal of Innovation, Creativity and Change. www.ijicc.net
Volume 5, Issue 1, November, 2019

Developing Entrepreneurship and Innovation acumen within students

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This paper used questionnaires to explore students' interest and understanding of entrepreneurship and innovation. It adopted a problem-solving methodology to develop and test a model that South African Universities of Technology could use to entrench a culture of entrepreneurship and innovation in students. The findings revealed that the majority of students, based on their study level and exposure, were interested in entrepreneurship and innovation. These findings were validated by the use of the developed model. The validation results compared positively with the findings of the questionnaires and also revealed that students were keen to establish business ventures of their own. In general, entrepreneurship and innovation should be entrenched in the curriculum and this paper provided the strategy on how to do so.

Keywords: *Entrepreneurship and innovation, student business ventures, problem-solving.*

INTRODUCTION

Youth unemployed is the world challenge. For example, the South African Quarterly Labour Force Survey (QLFS) revealed that more than three million South Africans aged between 15 and 24, were neither employed nor pursuing higher education (Stats-SA, 2018). However, unemployed gets lesser and lesser in older ages. The latter solicits for an answer on how or what could be done to solve youth unemployment.

Entrepreneurship and Innovation are known to be the key driver to any country's economic growth, success and survival (Millic, 2013; Kritikos, 2014). In this regard, the practice of entrepreneurship and innovation should be entrenched to the country's citizenry, in particular, the young people.

This paper was developed from a doctoral study that aimed at developing a model for university-sponsored student business. The paper views the concept of entrepreneurship and innovation as key in assisting to decrease or solve youth unemployment. The practice of entrepreneurship and innovation provides the ability to transfer ideas and knowledge into solving problems emanating from society and industry. It is important that the training of engineering students (undergraduate and graduate) and engineers (novice and professionals) should enhance their potential and ability to solve a problem while embedding creative skills to enable them to practise entrepreneurship and innovation. In this regard, using problem-solving methods or processes could be a good component to train those students and engineers. Haupt & Webber-Youngman (2018) argues that problem-solving processes tend to focus on the quality of the end-products or solutions and disregards the importance of the problem structuring steps. However, the paper proves that the amalgamation of entrepreneurship, innovation and the problem-solving process improves the importance of the problem structuring steps.

Against this background, this paper investigated how South African Universities of Technology could entrench the culture of entrepreneurship and innovation to their students. It used questionnaires to explore students' interest and understanding of entrepreneurship and innovation; then it adopted a problem-solving methodology to develop and test a model on how South African Universities of Technology (UoTs) could use assignments to entrench the culture of entrepreneurship and innovation to their students. This introduction is followed by a brief discussion on problem-solving as a theoretical framework that guided this study, then highlights the adopted methods by briefly discussing how the data was collected and analysed. The paper concludes by briefly discussing how the problem-solving method was adapted to develop a proposed model, how that model was tested and what the results were; then generally points to future research work.

PROBLEM-SOLVING

Engineering education literature overwhelmingly indicates that traditional curricula propagate linear thinking, which is not conducive to fostering the kinds of thinking needed when working in environments with complex systems (Haupt & Webber-Youngman, 2018). Engineering education adopts and involves applying a consistent, structured approach to the solving of problems. Ahmad (2011) advised that solving problems must be approached methodically, applying an algorithm or step-by-step procedure by which one arrives at a solution. In this regard, to begin solving a problem, an individual should firstly recognize and agree that there is a problem, then identify the problem root cause as some problems might have hidden origins.

Problem-solving is the process of finding solutions to difficult or complex issues. It is a process whereby the best outcome is determined for some situation, subject to certain constraints. It can be used to develop practical and creative solutions and to show independence and initiative. Adams, Kaczmarczyk, Picton, & Demian (2010) and Ahmad (2011) mentioned that there are different problem-solving models as illustrated in Table 1. The CCMIT teach that these problem-solving models are subdivided into two basic types: (i) algorithmic, and (ii) heuristic (https://ccmit.mit.edu/problem-solving/).

Inspiration Method	Polya Method	Woods Method	Myrvaagnes Method
Preparation	Define plan	Define problem	Define the problem
Incubation	Plan	Think about the problem	Identify key issues
Inspiration	Carry out plan	Devise plan	Collect/assess information
Verification	Look back	Carry out plan	Identify assumptions
		Look back	Break the problem into parts
			Model sub-problems
			Integrate solutions
			Test/validate
			Generalise the solution
			Communicate the solution

Table 1: Problem-solving methods (Source: Morgan, and Williams, 2013)

The algorithmic strategies are traditional step-by-step guides to solving problems, and they are best when there is a single path to the correct solution. While heuristic methods are general guides used to identify possible solutions. The popular heuristic model, **IDEAL**, is illustrated in Figure 1, and its abbreviation for the following steps: (i) **I**dentify the problem, (ii) **D**efine the context of the problem, (iii) **E**xplore possible strategies, (iv)

Act on best solution, and (v) **L**ook back and learn.

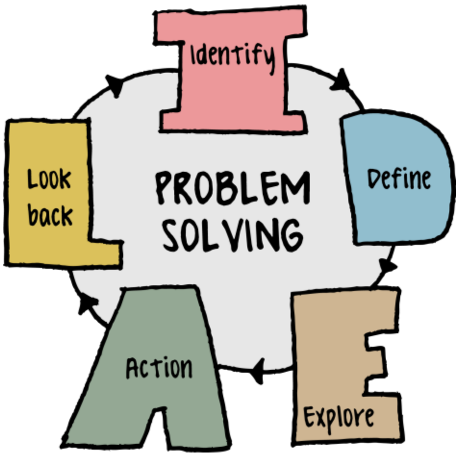

Figure 1: The IDEAL framework. (Source: https://ccmit.mit.edu/problem-solving)

Practising engineers are hired, retained, and rewarded for solving problems (Jonassen, Strobel, & Lee 2013). In this regard, lecturers should teach engineering students to solve practical problems using different problem-solving process' teaching methods (Adams, et., al, 2013), namely: (i) Thinking Aloud in Pairs Problem Solving (TAPPS) where problem-solving process skills are developed through the interaction of the problem solver and a listener, (ii) Brainstorming techniques for idea and solution generation for developing discrete stages of the process, (iii) Gantt charts for planning, implementation of checklists for evaluation and reflection, and (iv) Problem-based learning (PBL) exercises where curriculum is structured as a problem or series of problems, as opposed to a systematic presentation of subject content. Any PBL activity is made up of different components such as: setting the problem scenario, forming the teams, providing support, and allowing reflection on individual performance. Using PBL could help to prepare engineering students to solve practical problems.

RESEARCH METHODOLOGY

This paper adopted a pragmatic approach to research (Alzheimer-Europe 2009; Saunders, Lewis, & Thornhill, 2012, Glasgow 2013, Creswell, 2014). The pragmatics recognise that there are many different ways of interpreting the world and undertaking research, that no single point of view can ever give the entire picture and that there may be multiple realities (Saunders, Lewis, & Thornhill, 2012). Pragmatism opens the door to multiple methods, different forms of data collection and analysis including assumptions and worldviews (Creswell, 2014). According to Creswell (2014), the latter is well supported by the mixed-method research methodology which combines or integrate the qualitative (in which data tends to be open-ended without predetermined responses) and quantitate (in which data usually includes closed-ended responses) research.

The major reason for using mixed methods resonate with the fact that concerning data collection, all methods have biases and weaknesses; however, the use of both quantitative and qualitative data balance biaseness and neutralize the weaknesses of each form of data (Creswell, 2014). Literature (Creswell, 2009; Teddlie & Tashakkori, 2009; Morgan, 2013; Creswell 2014) identifies several types of mixed methods strategies. In this paper, the Convergent Parallel Mixed Method (CPMM) was adopted because it allows the researcher to collect both quantitative and qualitative data, analyse them separately, and then compare the results to see if the findings confirm or disconfirm each other. The key assumption of this approach is that both qualitative and quantitative data provide different types of information and together they yield results that should be the same (Creswell, 2014).

This paper aims to report on the development of the entrepreneurship and innovation model that was validated in an engineering class. In this regard, survey and action research methods were the two data collection methods adopted to satisfy the requirements of the CPMM.

Quantitative Data Collection: The Survey Method

A survey method uses questionnaires and interviews as data collection tools to question individuals on a topic(s) for a purpose of (i) describing certain aspects or characteristics of population; and/or (ii) testing hypotheses about the nature of relationships within a population (Dudovskiy, 2018). This paper used questionnaires in an attempt to answer the following research questions: (i) Do South African Universities of Technology's (UoT's) students understand entrepreneurship and innovation? (ii) Are South African UoT's students interested in entrepreneurship and innovation?

(i) ***Determining Sample Size*** – Using the South African Higher Education Management Information Systems (HEMIS) database, and two statistical sample size software: the Creative Research Systems (CRS) and RAOSOFT a sample size was defined for this study. At a time of conducting the study, HEMIS reflected that at least a total of 13764 UoTs' students were in the system. The CRS and RAOSOFT revealed that the sample size of at least 800 participants would make the study results significantly.

(ii) Collecting data – The plan for data collection was to draw a total sample of 1050 students (extra with 250 from the determined sample size) from six South African UoTs. After requesting the ethical clearances from the six UoTs, only five were approved and that reduced the targeted sample. Then, the e-mail method was used to distribute questionnaires to a total of 980 science, engineering and technology (SET) students. Of the 980 distributed questionnaires, 950 were returned (after frequent reminders to the academics who assisted with their students' e-mails). Of the 950 returned questionnaires, 886 were unspoiled, of which 405 were from Diploma students, 302 Bachelor of

Technology (BTech), 140 Masters of Technology (MTech) and 39 Doctor of Technology (DTech). Furthermore, of the 886 participants, 57% were male while 43% were female.

Qualitative Data Collection: Action Research Method

Action research is an approach in which the researcher and the research participants collaborate in the diagnosis of the problem and the development of a solution based on the diagnosis. In action research, group and class discussions are perhaps favourable data collection tools. At the time of conducting the study, the researcher was a lecturer of at least two classes of the SET category (Computer System Engineering, and Principles of Research for Information Technology students) for different groups of students for five consecutive years. In this regard, the students were divided into groups of five-to-seven members per group. The researcher used one of the two compulsory assignments and also the IDEAL framework, to test the students' understanding and interest in entrepreneurship and innovation through class discussions before and after students used the developed model.

RESULTS

Entrepreneurship is a multidimensional concept and the definition used depends on the focus of the research taken (Verheul, et al, 2001:4). Innovation is the process of creating something new of value that has useful application and significant impact upon an individual, a group an organization, an industry, or a society (Malele, Mpofu & Muchie, 2017). Societal and economic changes and challenges gave birth to entrepreneurship and innovation. Entrepreneurship cannot be de-linked from innovation. In this regard, the term or concept entrepreneurship and innovation is the process that leads to the development of new ventures based on the exploitation of new or existing knowledge (Elpida, et. al., 2010). Entrepreneurship and innovation are most often equated and linked to job creation than job consumption.

The Questionnaire

The above brief discussion was used to develop the questionnaire which tested students understand and interest to entrepreneurship separately from innovation, both entrepreneurship and innovation. In this regard, the following questions were answered:

(i) Do South African UoTs' students understand entrepreneurship and innovation?

Figures 2, illustrates students' understanding of what is entrepreneurship. It reveals that the majority of students in all study levels have a clear knowledge of what is entrepreneurship.

While Figure 3 illustrates students' understanding of what is innovation; and reveals that the majority of students in all study levels have a clear knowledge of what could be innovation.

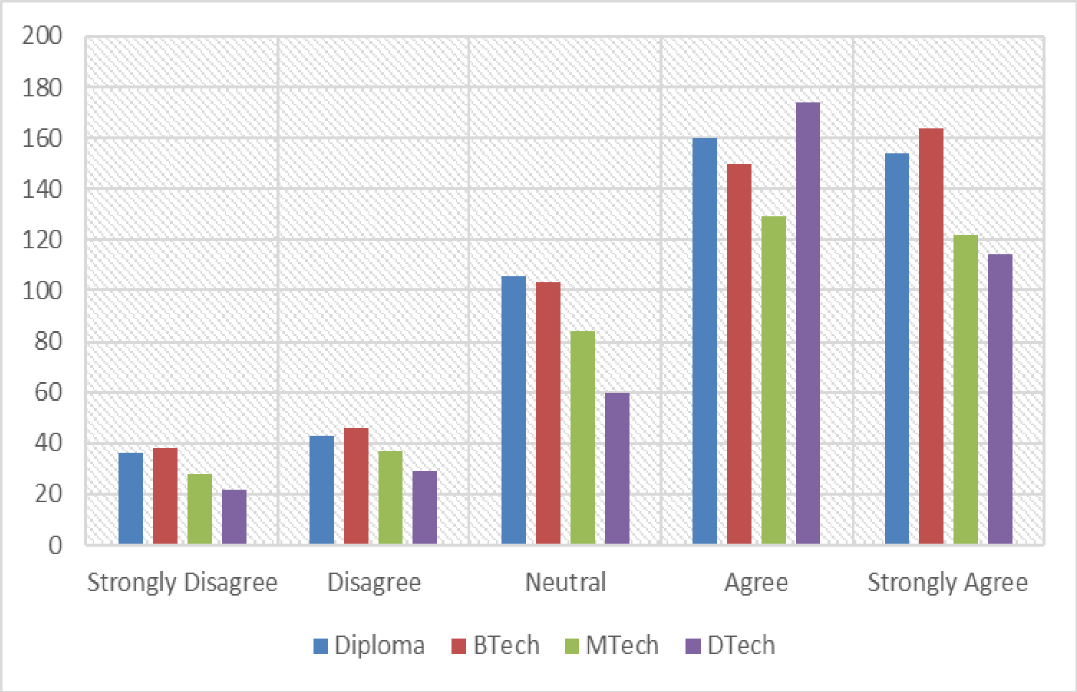

Figure 2: Students' understanding of entrepreneurship.

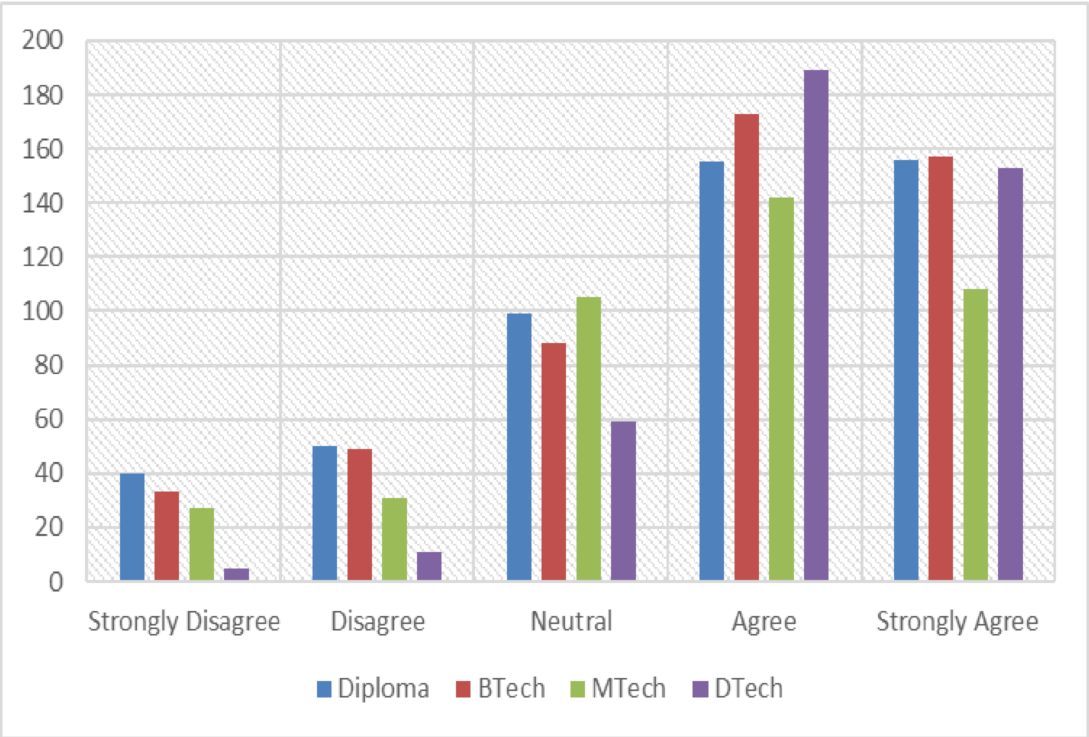

Figure 3: Students' understanding of innovation.

In general, Figure 4, reveal that most students had an understanding of entrepreneurship and innovation. This is because at least 76% of students agreed and strongly agreed that they understand the concept of entrepreneurship and innovation.

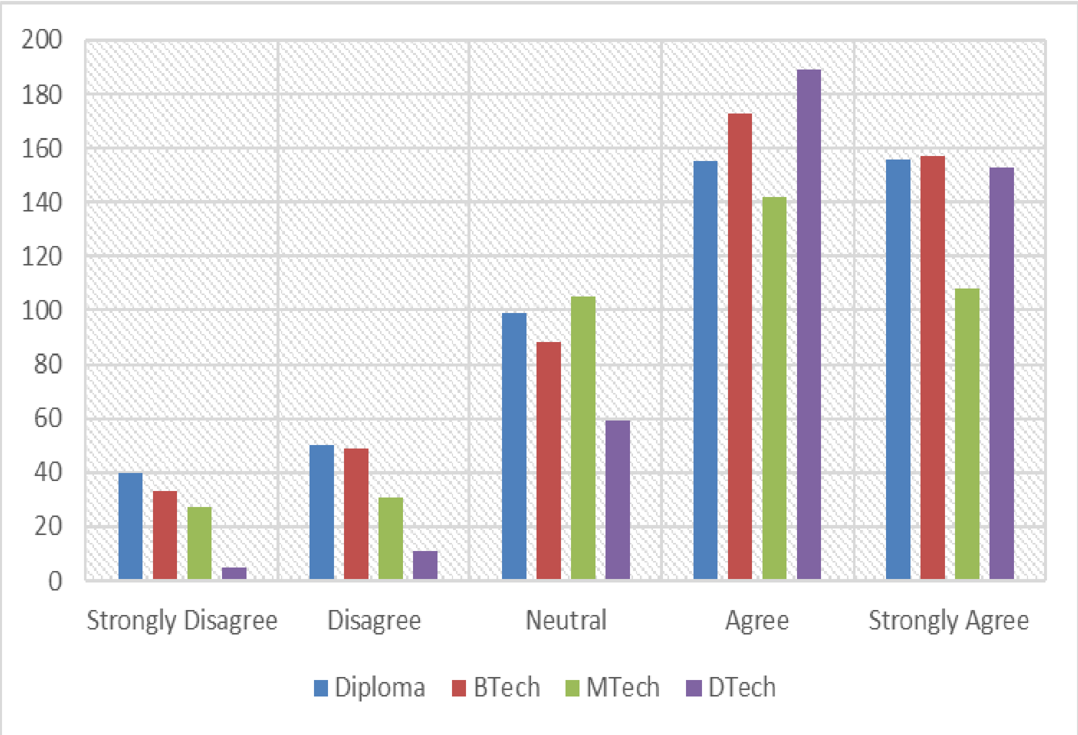

Figure 4: Students' understanding of entrepreneurship and innovation.

Figures 2, 3 and 4 are curvilinear and skewed towards students' agreeing and strongly agreeing with the response that reveals their understanding of entrepreneurship, innovation as well as entrepreneurship and innovation. Findings in Figures 2, 3 and 4, are contrary to the work by Edwards, Sánchez-Ruiz, Tovar-Caro, & Ballester-Sarrias, (2009) who argued that in general, students' ideas concerning innovation were confused, vague and incomplete. Edwards, et al. (2009) further argue that students usually do not distinguish between creativity, invention, research and development (R&D), and innovation.

As a general observation, while students understanding of innovation increases, so does that of entrepreneurship. Although most participants were male, the understanding of entrepreneurship and innovation is not gender-based but depends on the study level. This means that the further the students' graduates and proceed to the next level, the better their understanding of entrepreneurship and innovation. Malele, et al. (2017) argued that such students have a strong potential of establishing new ventures, the issues is that they were not adequately training in entrepreneurship and innovation.

(ii) Are South African UoT students interested in entrepreneurship and innovation?
Students develop interest and motivation when they are encouraged to explore and investigate new areas and ideas (Kolb, 2012). Exploring and investigating new areas and ideas with clear expectations demands self-belief. Van der Lingen and Van Niekerk (2015) said self-belief is a key characteristic of successful entrepreneurs. In other words, self-belief is an ingredient that sparks an interest in entrepreneurship and innovation. In this study, students' entrepreneurial and innovation interest was investigated (see Figure 5).

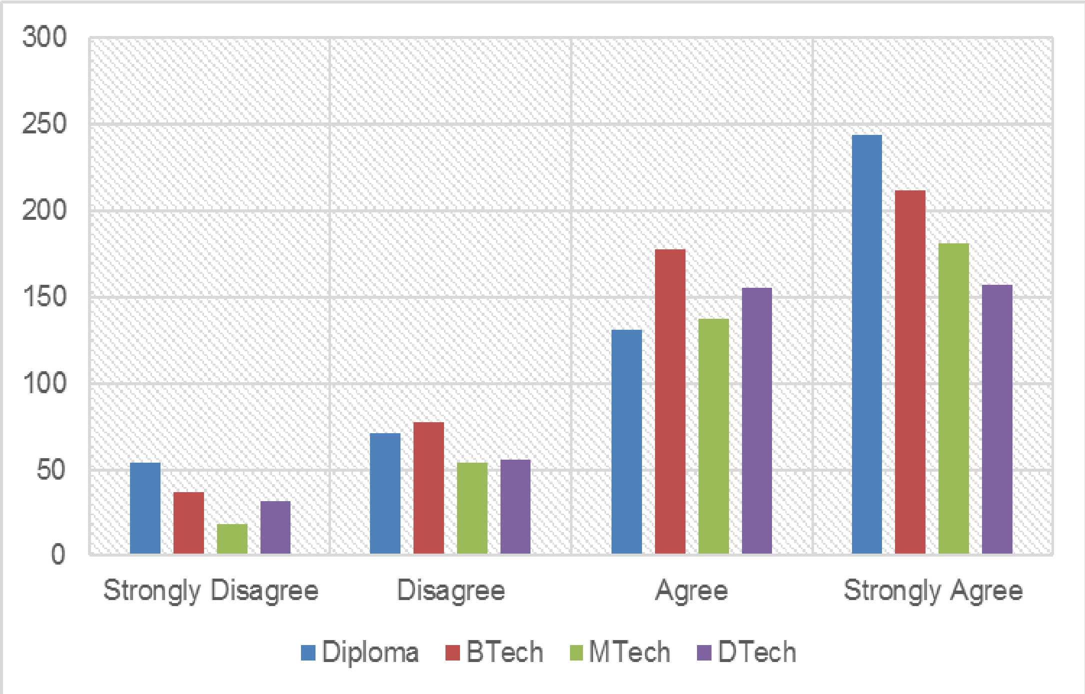

Figure 5: Students' interest in entrepreneurship and innovation.

In general, students strongly agreed with the statements that revealed their interest in entrepreneurship and innovation, as illustrated in Figure 5. It indicates that on average students are interested to engage themselves in an entrepreneurial and innovation activity. It should be noted that Diploma and BTech are mostly junior students who are mainly in their 20 to 30 years of age; in this regard, this investigation revealed that Diploma and BTech students had more interest in entrepreneurship and innovation than masters and doctoral students.

The latter means the younger people are, the better are the chances for them in engaging in entrepreneurship and innovation. Although, deeper understanding of entrepreneurship and innovation develops as they progress with their higher education studies and grow-up in life experiences. In this regard, the school-of-thought led to the development of a model which could be used to validate the entrepreneurship and innovation concepts in a classroom setting among young people.

Model Development

Adapting from the fact that students had understanding and interest in entrepreneurship and innovation as discussed above, through a doctoral study (Malele, Mpofu, and Muchie, 2017), an open innovation model known as the University-sponsored Student Business Ventures (USSBV), see Figure 6, was developed using design science and system thinking approach. The USSBV model comprises four main stages and a feedback loop that connects all stages. The stages are the (i) Ideation Stage, (ii) Agreement Stage, (iii) Business Research and Development, and (iv) Venture Creation Stage (Venturing).

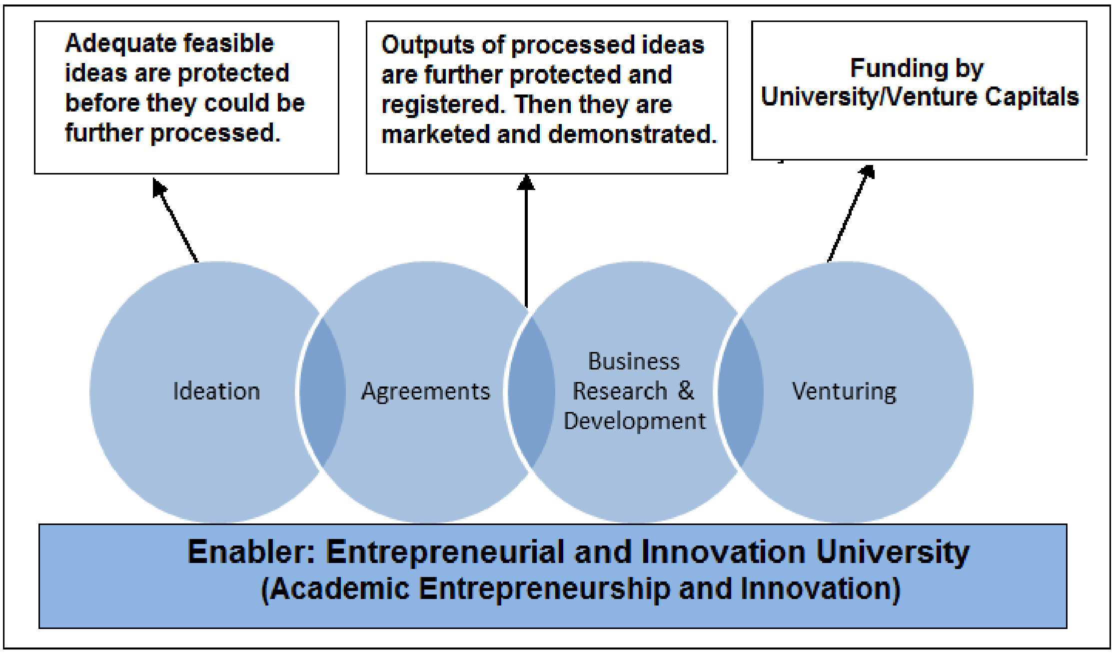

Figure 6: The University-sponsored Students Business Venture Model.

(i) **The Ideation Stage** – Since the USSBV model is an open innovation model, its Ideation stage emphasis that entrepreneurship and innovation ideas do not originate only from a single source (R&D projects), but from many other sources. In this regard, in a university context, USSBV model allows students to obtain ideas from patent search, community engagement, and intuitiveness (i.e. brainstorming sessions, normal creativity, etc). The latter will seek to address challenges originating from students' environment or communities.

The ideation stage is an interactive process that involves finding the (a) needs (mostly through the methods that are discussed above), and (b) formulating and determining feasibility. An ideation stage is a recognition of opportunities stage for feasible ideas, which when found, they go through the agreement stage.

(ii) **Agreement Stage –** The ideation stage is followed by the agreements or intellectual property rights (IPR) stage which involves patent registration, signing of agreements of understanding and agreements of exploiting the ideas. These agreements are signed between the students (as potential venture founder or chief executive officers) and the university (as a sponsor). To protect all parties, in a case whereby students obtained ideas from community members such as indigenous knowledge holders or practitioners, an agreement between the student(s), the community member, and university should be signed.

In this stage, the university has to use its policies, assets, and resources to assist students with the development of business agreements. It should be noted that almost all ideas need to go through the intellectual protection (IP) process. Some ideas could be protected through other registration processes (i.e. terms of reference, memorandum of understanding, etc). Thereafter, the ideas will be taken to the R&D stage.

(iii) **Business Research and Development –** The research and development (R&D) is at the heart of innovation. Unless R&D is effectively transferred to the marketplace and communities, its benefit to the locality or economy will be limited (Yusof, 2010). The signatures by different stakeholders on (ii) above, regarding the suitability of ideas, allow the student(s) and the university (designated personnel) to begin conducting some necessary R&D activities such as idea-to-product development, business and marketing R&D, customer management processes, etc.

The outputs of this stage could either be prototypes or products or services which should be marketed and demonstrated (or vice-versa) to the: (i) selected target market (i.e. those who suggested ideas, and the solution(s) was conceptualized for, or selected group which marketing research identified as potential market/buyers), and (ii) entire potential market (i.e. expansion of buyers). It is at this stage when part of venture capital funding and university funding will be important and necessary because some of the prototypes or products or services will need to be protected through agreements and/or IP protection processes. In this regard, it should be noted that some R&D activities will yield ideas and solutions that might need to be referred back to the agreement stage for them to be protected. For completing such an activity, the USSBV model comprises a feedback loop. Once the necessary R&D activity is conducted, its products or outputs being marketed and demonstrated to the targeted market; then, the results of this stage foster the beginning of the venture creation stage.

(iv) **Venture Creation Stage (Venturing)** – In this stage, the USSBV's stakeholders strategically form and register an organization that will be used to commercialize the outputs of the stage (iii) above. Such a venturing organization will seek necessary certification for developing, marketing and demonstrating the necessary prototypes or products or services. The structure of the organization will be in such a way that the student(s) will be founding members and perhaps CEOs.

In this stage, most of the agreed venture capital and university funds will be needed because other entrepreneurial and innovation activities should be conducted like further marketing, salaries of new employees, scale-up of the product or prototype or services, etc. This stage produces more ideas that are feedback, mostly to the ideation stage; however, depending on how they are conceptualized, they could be routed to any stage of the USSBV model for further development and exploitation.

Model Validation
To validate the USSBV model, the following question was asked: "Could the USSBV model be capable of addressing students' unemployment problems". Students' unemployment is a complex and difficult problem. In the sections above the IDEAL framework was presented as a problem-solving process aimed at finding solutions to difficult or complex issues. In this regard, the USSBV model was compared to the IDEAL steps to validate whether or not the USSBV could be viewed as a potential problem-solving model.

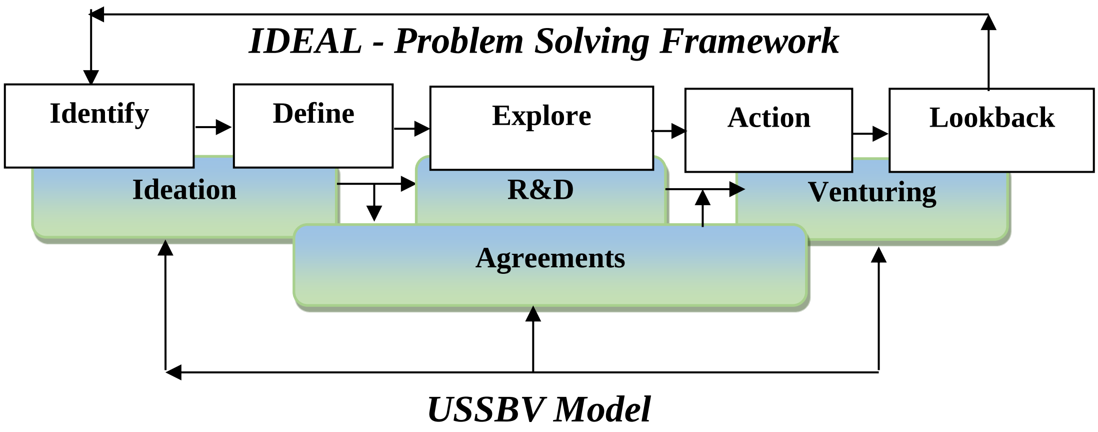

Figure 7: Mapping IDEAL and USSBV Model.

The USSBV ideation stage could be mapped to relate to both the **Identify** and **Define** steps of the IDEAL framework (as illustrated by Figure 7). In the IDEAL framework, the **Identify** step is used to identify the problem and the **Define** step used to define the context of the problem, while in the USSBV model, ***Ideation*** is used to identify a potential problem that needs to be solved through entrepreneurship and innovation ideas, understand the problem and ideas, then swift for a feasible idea.

The **E**xplore step of the IDEAL framework explores possible strategies, this mapped to the USSBV's ***Agreements and R&D*** stages as they use the idea from ***Ideation*** stage to explore feasible prototypes or products or services as the idea's outputs. In the USSBV's ***Agreements and R&D*** prototypes or products or services will be protected and marketed; this link well to exploring strategies. The IDEAL framework, **Action and Lookback** steps began to act on implementing the best solution and learn from the process. This relates to the USSBV's ***Venturing*** stage which focuses on developing an organization that will certify and commercialise the prototype or product or services that would have been the outputs of other stages. Funding will be needed in establishing the organization and commercializing the prototype or product or services, then stakeholders should take action of getting the necessary funding from venture capital and university funds. This stage will produce more ideas that are feedback, mostly to the ***Ideation*** stage; however, depending on how they are conceptualized, they could be routed to any stage for further development and exploitation.

Model Testing

At Tshwane University of Technology (TUT), Faculty of Information and Communication Technology (FoICT), wireless and mobile communication network module known as Network System IV (NSY401T), is offered in the second semester to students registered for the Bachelor of Technology (BTech) in Computer Engineering Systems (CES). The author was a lecturer of the NSY401T from 2013 to 2017, while in the same period being a doctoral student. The assessments of NSY401T comprise two major assignments, two-semester tests and examination. The assignments and semester tests are used to compute students' predicate mark (PM). Examination results are computed as examination mark (EM). The student is promoted if the average of the PM and YM, known as the year mark (YM) equals to 50% and above (i.e. YM = ½ [PM + EM] = ≥ 50%).

The NSY401T assignments were designed by the author to gauge the students' theoretical understanding (i.e. assignment 1) and the critical thinking through practical solutions (i.e. assignment 2). The theoretical assignment aimed to build the students' research skills because the assignment end product was to use systematic literature review and produce an essay or survey document looking at one of the wireless and mobile communication network topics like 5G). While the practical assignment aimed to introduce PBL to students by allowing them to use their NSY401T concepts to identify societal and economic problems and ideas that could solve such problems. The USSBV model was presented to the students as a PBL method and as a guiding model to help them exploit the identified ideas and solutions either as prototypes or product or services. To achieve the outputs of assignment 2, students were divided into groups of five to six members. The groups were allowed to set the problem scenario by applying ideation techniques such as patent search, brainstorming, etc.

In this wireless and mobile networking ideas that could solve societal challenges were brought forward and reported by different groups to the researcher. However, some students felt that they need to continue with their potential solution and build some models that could support and test the solution workability of their ideas. Of particular importance was a group of five students (comprise of two members employed as school teachers, two unemployed, and another one employed as a technician) who used Design Thinking for Educators toolkits (www.ideo.com) to develop a web-based physical science simulation software for the classroom. The simulation is accessed through mobile phones and has a chat platform embedded within it. The chat platform was facilitated through an app that uses the ShareIt algorithm. The author assisted the students to develop a technical drawing that illustrates the way their simulation works. Furthermore, the author helped the students to create the simulation as proprietary software in which a license fee will be needed for its usage. The main target market for this software was the South African Department of Basic Education. Then, the author requested the students to submit their work for funding purposes through the university's funding partners such as the South African Technology Innovation Agency (*www.tia.org.za/funding*), and as well as compete in innovation competitions such as the GAP ICT hosted annually by The Innovation Hub Management Company (TIHMC) (*http://test.theinnovationhub.com/gap/ict/*) which is the subsidiary of the Gauteng Growth and Development Agency (GGDA) a government agency.

At the time of writing this paper, the group agreed that the two unemployed students' will join the TIHMC's Maxum Business Incubator to further pursue their idea and there three employed will contribute some living allowance as a form of stipend until an incubator or sponsor adopted the idea. In 2017, a follow-up made with the students revealed that they were currently sponsored by an angel investor through a concept called crowdfunding. Unfortunately, the latter happened out of the university premises since the students graduated in 2016 and they did not share the ideas with the university.

Lesson Learned

As the lesson learned, the university must create a platform in which they could identify and work with crowd-funders or venture capital investors during the early stages of identifying potential entrepreneurial and innovative ideas from students. The students' participation rate to the entrepreneurial and innovation activity was impressing. Throughout the years (2013 to 2017), when students were asked about the inclusion of entrepreneurial and innovation activity in their NSY401T course, on average about 97% of students agreed and strongly agreed that such an inclusion would be beneficial to them.

Through discussions, the students pointed out that the activities stretched their thinking capabilities and allow them to be assessed on ideas that could be exploited and help them to foster new companies. In terms of students' interests towards entrepreneurship and innovation, the author concluded that the success rate of students' ideas is a function of their attitude, motivation, and interests:

$$\text{Ideas success rate} = f\,(\text{attitude, motivation, and interests}).$$

The general observation was that assignment 2 allowed students to (i) reflect on the group performance and dynamics, (ii) ways of collecting and collating potential entrepreneurial and innovative ideas, and (iii) ways of engaging with the university to exploit any potential idea which could bring commercial profits.

CONCLUSION

While students' understanding of innovation increases, so does their understanding of entrepreneurship. In this paper, although, most participants were male, the understanding of entrepreneurship and innovation is not gender-based but depends on the study level.

The main contribution of this study is the methodology concept known as USSBV model that could be used to entrench the culture of entrepreneurship and innovation by including entrepreneurship and innovation activities within students' curriculum.

The inclusion of entrepreneurship and innovation activities in the curriculum appeared to ignite students' interest in establishing the joint-ventures with the university. This will help students to address their employment insecurities. Research on the success of these joint-ventures poses a question for future research. The second aspect that requires future research would be to investigate the policies of stakeholders which promote the inclusion of entrepreneurship and innovation activities in engineering curriculum such as exploiting existing patents.

ACKNOWLEDGEMENT

This paper was developed from a doctoral study that aimed at developing a model for university-sponsored student business ventures. In this regard, the author like to thank the Department of Industrial Engineering, Faculty of Engineering and Built Environment at Tshwane University of Technology (TUT) in particular Professor Mammo Muchie and Professor Khumbulani Mpofu for allowing that a doctoral study could be conducted under their auspices. The author acknowledges and thanks the Gibela Railway Consortium, the National Research Foundation and the Department of Science and Technology for their support on this work.

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