INNOVATING ENGINEERING STUDENT CURRICULUM WITH ENTREPRENEURSHIP

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ABSTRACT

Innovating Engineering Students' Curriculum with Entrepreneurship introduces the framework of entrepreneurially minded learning (EML) centred on observations, curiosity, connections, and creating value. Exploration of each of these components, instil a variety of different active learning techniques that can be applied to encourage engineering students towards entrepreneurship. Key components for making a strong learning experience for the students including learning objectives, problem statements/opportunity recognition, and teamwork are applied so as to foster the principles learned to create value and share a teaching technique for particular topics in their discipline.

This paper presents a model towards producing entrepreneurial engineers. The identification of opportunities for entrepreneurship, integration into existing courses and implementing continual improvement of particular entrepreneurship practices (i.e., mechanisms, procedures, tools, frameworks) are presented for adoption to promote entrepreneurship to engineering students. As such a case study methodology is adopted for this study with summaries and case analysis of four cases of entrepreneurial learning in the premier Technical University in West Africa (Alpha) in order to unravel the relationship between technical skills, theoretical knowledge and opportunities recognition and exploitation skills. Their relative advantages and disadvantages are discussed based on the interviews with students of Alpha undergoing different phases of entrepreneurial training. The analyzed cases help to identify various positions in the integration stage and mind-set transformation era of the engineering students. This paper concludes with some propositions and a robust model for implementation towards producing entrepreneurial engineers.

Keywords: Entrepreneurial Engineers, Curriculum, Entrepreneurially minded learning, Case study

INTRODUCTION

In Africa, enterprise creation and entrepreneurship are considered as vital in terms of their contribution to economic development, regional economic development and employment generation. As such, there is a growing understanding in Africa that it is important to encourage an entrepreneurial culture with the right mindset, entrepreneurial skills and career possibilities. The communique on the African Engineering Education Association (AEEA) highlighted some of the current issues and modifications required in teaching engineering students so that they are not just engineering students but also entrepreneurially minded. Issues connected with such transition was one of the several workshops discussion in the September, 2019 International Conference of AEEA recently in Lagos, Nigeria. Some of the highlights emphasized that engineering education need to take cognizance of local applications. Another is that, the curricula in engineering and technology education in Africa need to be improved by integrating technology enabled teaching and learning environments particularly with Information and Communication (ICT) systems and internet based systems. One other assertion is the fact that engineering and technology education could integrate aspects of entrepreneurship as that would be vital to the well-being of our economies and societies in the African context. That motivation, that is, the importance of entrepreneurship and engineering education for a more conscious next generation of decision makers and the need for effective pedagogy for entrepreneurship to develop the manufacturing sector are the basis for this study. In this study, the repertory grids which are part of George Kelly's (1955) Personal Construct Theory (PCT), were used to facilitate the analysis of entrepreneurial networks during the pre-organization stage and a similar application can, however, be assumed in a post-creation setting. That pedagogical approach is different from the system where entrepreneurship courses are either electives or standalone courses with little or no integration into the main curriculum.

Description of the tool

The repertory grid technique is a method for discovering personal construct systems. Its purpose is to provide some information about the manner in which our system of personal constructs is as well as showing its barriers and potential benefits (Beail, 1985). In general such matrix tables contain:

Elements: the presented stimuli for discussion.

Constructs or concepts derived from the participants.

Ratings, that is, hierarchical values given by the interview participant (Aranda and Finch, 2003).

Beail (1985) refers to the ratings as "linking mechanisms" as they reveal the assessment of each element on each construct. One of the advantages of repertory grids is that though they have qualitative data, they can be analysed statistically. Hence, it is possible to identify correlations between elements and concepts within a grid and links between the grids themselves (Aranda and Finch, 2003; Bryman and Bell, 2003).

2. *Entrepreneurship among undergraduates in Africa*

Enterprise creation by higher education graduates is still a marginal phenomenon in Africa. Open change is needed to transform the mindset of undergraduates from a managerial society: where managers do things right — to an entrepreneurial society, where leaders do the right things. That could be a possibility through entrepreneurial minded learning and a shift from reliance on deterministic and stochastic change, to a situation of open change. The dream of manageability is coming to an end. The system dynamics become chaotic - rather than rigid - and a creative leadership approach based on structural knowledge is adopted and delivers competence, instead of a reactive one, based on information, existing behavior and learnings from past mistakes.

Entrepreneurial minded learning is results oriented, rather than rule oriented, and follows that educating engineering undergraduates as managers portrays efficient avoidance of mistakes, while educating them as entrepreneurial engineers is focused on effective learning from past mistakes, information and observations. A curriculum contains structured document that depicts the philosophy, objectives, learning experiences, instructional resources and assessments that comprise a specific educational programme. Evaluating the present engineering undergraduates' curriculum reveals the importance of recognizing the entrepreneurial elements of the engineering education and how to instill some practical skills and mindset transformation in engineering undergraduates before infusing such learning into their curriculum towards the development of an entrepreneurial engineer (Idris & Adeyemi, 2018).

Innovating engineering education with entrepreneurship

In 2017, Alpha created a Directorate for Technical, Vocational and Entrepreneurship Education (TVET) in teaching and research to help the different stakeholders in education such as professionals and decision makers at different levels to deal with the multifaceted challenges influencing the educational systems towards producing entrepreneurial engineers among others. One of the vital issues of concern was how various teaching methods and the acquisition of knowledge and skills could be developed in line with entrepreneurship, scientific progress, new technologies and the diversification of the undergraduate students. Other perspectives related to the role of innovation in the lecture room and the question of which educational systems and universities would be suitable in the future (Istance and Shadoian, 2009). These issues are still relevant today, given the sphere of uncertainty created by the economic crisis. There is no doubt, as Istance and Shadoian (2009) conclude, that the recent social and political changes have triggered questions about the suitability of analysis and methods of teaching in Europe. This perhaps, is no different in the present African situation. Given such situation which makes experimentation and innovation in pedagogy imperative, Istance and Shadoian (2009) conclude that the aim to experiment in education (particularly in

engineering education) has caused a wave of innovation around the world. As a reaction to the potential positive social and economic effects of entrepreneurship, Alpha is advancing entrepreneurial minded learning and behavior in the West African context. Moreover in this context it is important to enhance the engineering undergraduates' awareness of the definition of entrepreneurship as related to their primary engineering course of study. As a result, there is a need to introduce entrepreneurship courses into every degree programme for at least two – three years in order to encourage and maintain an entrepreneurial culture in our continent. Though, the level of innovation of such programmes and courses varies, however. For Alpha, apart from the regular lecture room courses, a two weeks practical sessions is adopted at the beginning and end of each semester. In fact, as Verzat et al. (2009) and Wankat et al. (2002) highlight that there is not much literature available about innovative approaches to Entrepreneurship teaching and much less entrepreneurial engineering teaching. Against this background the four cases presented here from Alpha aim to fill a gap in the existing literature. The innovative pedagogy experimentation is placed in the context of four entrepreneurial activities in Alpha.

METHODOLOGY

As Yin (2009) argue, qualitative methods are suitable for exploratory studies and the case study method has been part of this trend. Indeed Stake (2003, p. 435) confirms that case studies have become one of the typical ways to do qualitative inquiry and they "are not a methodological choice, but a choice of what is to be studied". This study is based on four case studies and aims to compare and contrast innovative entrepreneurial pedagogy among engineering undergraduates in Alpha. The sampling criteria is the degree of technicality involved in their choice entrepreneurship activities. The underlying objectives were to learn from the different pedagogical and cultural approaches, that is, derive learning in terms of recognizing individual strengths and weaknesses, opportunities and threats for the institutional partners. Entrepreneurial skills acquisition program was conducted for all students in Alpha but our focus was on the engineering students in activities such as systems security, cosmetology, shoemaking, electrification, refrigeration and air conditioning, automation, ankara craft, advanced product development/3D printing, fashion designing, event management, agripreneurship, paints and paints production just to mention a few. This particular study considered four cases of: advanced product development, automation, systems security due to the degree of technical skills involved in the training. Ankara craft was the fourth entrepreneurial activity chosen to provide theoretical sampling.

The cases discussed in this study represents two opposite ends of the spectrum of innovative pedagogical tools available in Entrepreneurial teaching ranging from three fully-fledged cases of a "practice firm" to an individual innovative teaching module, taught as a stand-alone course. The two approaches were chosen as they contrast the traditional approach of understanding entrepreneurship as a process requiring holistic and action-oriented teaching with an approach that draws on cognition and in particular on repertory grids, the methodological tool of Personal Construct Theory (PCT) which was developed by George Kelly (1955).

DISCUSSION AND FINDINGS

Case1: Ankara craft was started in order to use Ankara fabrics to make different accessories and different outfit combinations (See Fig 1.0 below). The company is in the production of: Ankara slippers, Ankara Bow Tie, Hand Fans, Ear rings, Neck chokers, Phone pouches and other house hold commodities with different shades of Ankara Fabrics

Figure 1.0: Various products with Ankara crafts

Students acquire knowledge on how to design and make affordable cultural products both for fashion and the beautification of homes. The cultural products perspectives could be instilled into the engineering curriculum so as to encourage the adaptation of products to meet societal needs before extension as international brands. The mode of teaching reveals the facilitator as an initiator, moderator empowerment coach and observer in the entrepreneurial process.

Case Two: Advanced product development involves designing products in 3D models and later producing the physical products with the aid of a 3D printer. The teaching process helps the conceptualization skills of the engineering undergraduates. It further develops their ability to brainstorm with an unknown customer towards the production of innovative products. Professional skills and competences of the practice-firm does not only include expert knowledge in enterprise management but also multidisciplinary elements going beyond, the so-called key qualifications. The latter include methodological competences such as problem solving capabilities and social competences such as the capabilities to network, interact and to take responsibility (Rita Klapper, 2010) specifically in acquiring customers or when negotiating delivery terms or loans application. The mode of teaching portrays the facilitator as initiator, moderator and observer, while

students learn by self-driven initiatives. Engineering undergraduates could improve their professional skills through the iterative process of practice - theory - practice and a higher level of autonomy and fresh insights towards developing into an entrepreneurial engineer. Considering Case 1, the instillation of products adaptation is stressed for inclusion in the engineering curriculum while case 2, touched development of products through the practice-theory-practice philosophy (see Fig 1.1 below). That leads to a proposition as: *The iterative process of practice-theory-practice is a fundamental requirement in the engineering curriculum for developing entrepreneurial engineers.*

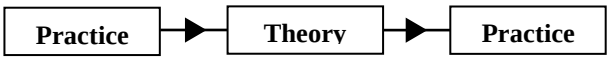

Fig. 1.1 EML Iterative Process

Case Three: Automation is the technology by which a process or procedure is performed with minimal human assistance. Automation involves the use of various control systems for operating equipment such as machinery, processes in factories, boilers and heat treating ovens, switching on telephone networks, steering and stabilization of ships, aircraft and other applications and vehicles with minimal or reduced human intervention. In teaching the entrepreneurial aspects of engineering, an appropriate methodology is vital as that could help students to immediately understand and learn entrepreneurial actions. Teaching concepts that are action-oriented, holistic, appealingly, participant-orientated, and promote reflection become increasingly important in entrepreneurship education (Rita Klapper, 2010) and much more in entrepreneurial minded learning of engineering. In teaching automation and its principles, the simulation method is often used because it is an activity-based didactical concept, used to teach students different competences simultaneously. Simulation of automation is the process of providing students with entrepreneurial minded learning of real operations in an imitational setting but often leads students to practical experience through a cyclic process (See Figure 1.2 below) of practice-theory-practice.

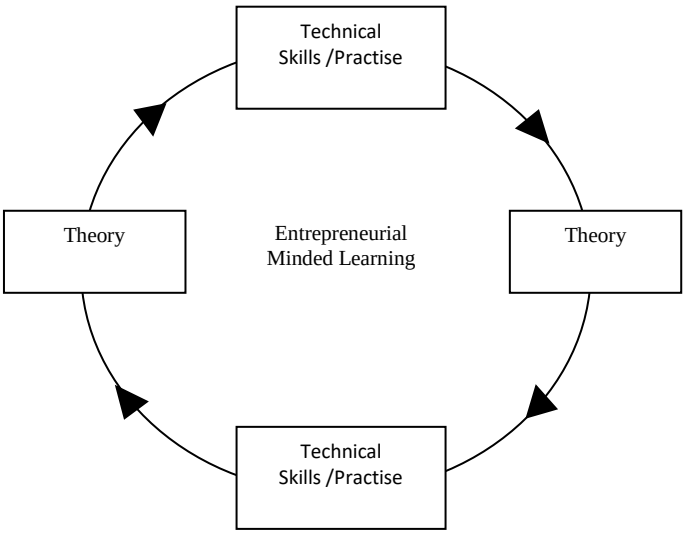

Fig 1.2: EML Path Dependency Cycle

Such process enable engineering students' possibilities to understand, experience and evaluate the outcomes of risky and costly decisions in a simplified model situation reproducing reality but with no exposure to any risk per se. The simulation methods used in teaching automation are manifold and versatile and include action based methods like role plays, case studies, practice firms, junior companies and computer simulations.

Case Four: System security (SS) is used in securing properties and/or individual with the aid of close circuit television (CCTV) and other accessories (see Fig 1.3 below).

Fig 1.3: Accessories for systems security projects

Some of the systems security programs involves access controls - which prevent unauthorized personnel from entering or accessing a property. SS also involves protecting information no matter where that information is, that is, in transit (such as in an email) or in a storage area. The detection and remediation of security breaches, as well as documenting those events is another SS program. These system security program aims to educate entrepreneurial engineers through an activity-based and participant-orientated didactic approach. That will help in the development of entrepreneurial engineers (Goldberg, 2006) through a cyclic and iterative process. With reference to case three and four, a proposition is put forward as: *The cyclic process of practice-theory-practice is essential in developing entrepreneurial engineers.*

Close attention to the specific elements of the four entrepreneurial activities reveals an interlinking (Figure 1.4 below) of each of the activities with the practice – theory - practice paradigm which is an encouraging effort to identify opportunities for entrepreneurship, integrate learnings into existing course curriculum and implement continual improvement of the chosen specific entrepreneurial practices with either mechanisms, procedures, tools or frameworks towards promoting entrepreneurial minded learning to engineering students.

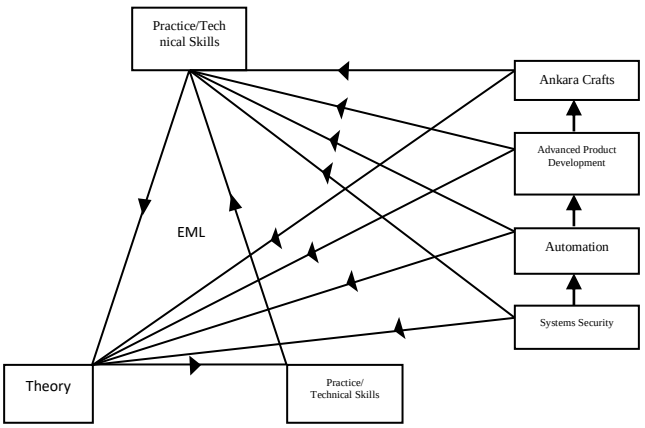

Fig. 1.4: Interlinking EML Skills Triangle with Entrepreneurial Activities

Table 1.0: Similarities and differences between Alpha innovative teaching practices

Approach	Ankara Craft	Advanced Product Development	Automation	System Security
Objective/Opportunity Recognition	Using local fabrics to design and make affordable cultural products	Simplify the production of complex products in good time	Fast and smooth operations without human assistance	Enhancing security levels in challenging or risky environments
Tool	Course component and activities based	Integration of stand-alone course components, activities based, conceptualization and machine learning	Course component, simulation and activities based	Course component, intuition and activities based
Role of Facilitator/Student	Facilitator as initiator, moderator and observer, but later empowerment of student	Facilitator as initiator, moderator and observer, self-driven learning by student	Facilitator as initiator, moderator and observer, but later empowerment of student	Facilitator as initiator, moderator and observer, but later empowerment of student
Initiators	Developed by a graduate at a University and applied in entrepreneurial pedagogy	Developed by a graduate at a University and applied in entrepreneurial pedagogy	Developed by a professional as an entrepreneurial pedagogy	Developed by one researcher, tested in Phd research, later applied in entrepreneurial didactics
Activities	Encourage understanding of business reality through start-up; promote personal development; promote a realistic view of entrepreneurship	Encourage critical reflection and options development; make complex thought processes visible; elicit student perception of network members; promote personal development	Encourage critical reflection and options development; make complex processes simplified; promote personal development	Understand members role in start-up, encourage critical reflection and make complex hidden processes visible; elicit student perception of network members; promote personal development
Underlying theories / Theoretical skills	Entrepreneurship as a Process, Interdisciplinary approach	Interdisciplinary approach linking entrepreneurial Network theories and PCT (cognition-based approach)	Interdisciplinary approach and PCT (cognition-based approach)	Interdisciplinary approach linking entrepreneurial Network theories and PCT (cognition-based approach)
Focus of training / Technical Skills/ Value	Holistic, activity and participant orientated	Importance of entrepreneurial network for a start-up; bringing concepts to reality.	Importance of entrepreneurial network for a start-up; simplifying interconnected processes	Importance of entrepreneurial network for a start-up; discovering unclear activities in real time without previous understanding
Work pattern	Teamwork	Teamwork	Teamwork	Teamwork
Entrepreneurial Intention of students	Not fully developed	Not fully developed	Not fully developed	Not fully developed
Software Use	No	Yes	Yes	Yes
Advantages	Encourages independent acting and self-employment; empowers independence, confidence, creativity and team work;	Evaluates the complete process of network analysis, ending with recommendations of how to adapt network for a successful start-up; makes the complexity of start-up activities visible, creativity, confidence and team-work.	Makes the complexity of start-up activities visible	Makes the complexity of start-up activities visible Cost effective, if with monitoring services
Disadvantages	Potentially time-consuming	Potentially time-consuming	Does not reproduce true to life situation Potentially time consuming	Potentially time-consuming

The blending of the engineering curriculum with entrepreneurship activities provides undergraduates with a curriculum oriented towards entrepreneurial minded learning suitable to produce entrepreneurial engineers who can solve societal, environmental, and technological challenges. Such curriculum provides students with:

- Evidence-based thoughts in order to empower the students in order to support or reject ideas based on logic, experimentation and data.
- Skills to develop self-direction through self-driven lifelong learning especially from previous mistakes.
- Calculated risk taking abilities to consider multiple options and weigh against possible negative results before making a decision or choice.

CONCLUSION

This paper has provided two examples with innovative pedagogy in entrepreneurship teaching, in a singular context but with multiple dimensions. The examples from all the entrepreneurial learning in Alpha focussed on “practice” with all its various activities and decision-making processes (See Table 1.0). One of the key lessons from this study which is innovative to our

standard teaching strategies is the 'activity-based' didactical concept of teaching the entrepreneurial perspective of their primary engineering course of choice.

The researchers concluded that the conventional theoretical approach and the activity based concept, though different in focus, application and extent, are potentially complementary. Thus, the activity based didactic concept could be integrated in the curriculum of future entrepreneurial engineers as the merits of the concept and its application in entrepreneurial learning situations were recognised. Also interesting, is the wider concept of: 'practice-theory-practise', which underlines the possibility for further collaborative attempts in developing joint innovative pedagogical tools. This study proves the transferability of the repertory grid teaching as an innovative pedagogical approach which has already been experimented within European, but also Asian contexts. Although further research is required so as to decide whether these approaches are unadapt ably transferable to different cultural contexts especially in Africa, both authors remain very positive about cross-cultural collaboration in engineering entrepreneurial pedagogy as this encourages learning and exchange of innovative ideas and concepts at an international level. One venue where such engineering entrepreneurial learning has been emphasized is the African Engineering Education Association's Forum which has been happening for about seven years formed at the University of Lagos, Nigeria where researchers and teachers have been collaborating in multi-cultural research activities aiming to exchange ideas and tools about engineering education in Africa and in particular, entrepreneurship learning studies, but also innovative engineering entrepreneurship pedagogy across African frontiers.

Other Findings of this study is similar to that of: Rita Klapper, 2010 who note that entrepreneurial intention is not very developed among young people in France, which is similar to students of Alpha in Nigeria. The majority of Alpha engineering students are not attracted by a career as an entrepreneur and rather prefer to work for a large company, consultancy firm, become a civil servant or enter the public sector (Rita Klapper, 2010).

REFERENCES

Aranda, G. and Finch, E. (2003), "Using repertory grids to measure changes in risk-taking behaviour", *Journal of Construction Research*, Vol. 4 No. 1, pp. 101-14.

Beail, N. (1985): *Repertory Grid Technique and Personal Constructs: Applications in Clinical and Educational Settings*, Croom Helm, Beckenham.

Bryman, A. and Bell, E. (2003), Business Research Methods, Oxford University Press, Oxford.

Istance, D. and Shadoian, V. (2009), "Education innovante", *L'Observateur de l'OCDE,* Nos 270/271, De´cembre.

Idris, M.O. and Adeyemi, O.A., (2018), Imparting Entrepreneurial Mindset Into Future Engineers Through An Integrated Entrepreneurial Engineering Curriculum: Proceeding of 2018 SEET Conference. Akure. Nigeria.

Kelly, G.A. (1955): The Psychology of Personal Constructs, Vol. I, Norton, New York, NY.

Rita Klapper Silke Tegtmeier, (2010),"Innovating entrepreneurial pedagogy: examples from France and Germany", *Journal of Small Business and Enterprise Development*, Vol. 17 No. 4, pp. 552 – 568

Stake, R.E. (2003), "Case studies", in Denzin, N.K. and Lincoln, Y.S. (Eds), *Handbook of Qualitative Research*, 2nd ed., Sage Publications, Newbury Park, CA, pp. 435-54.

Verzat, C., Byrne, J. and Fayolle, A. (2009), "Tangling with spaghetti: pedagogical lessons from games", *Academy of Management Learning and Education*, Vol. 8 No. 3, pp. 356-69.

Wankat, P.C., Felder, R.M., Smith, K.A. and Oreovicz, F.S. (2002), "The scholarship of teaching and learning in engineering education", in Huber, M.T. and Morreale, S. (Eds), *Disciplinary Styles in the Scholarship of Teaching and Learning: Exploring Common Ground*, AAHE/Carnegie Foundation for the Advancement of Teaching, Washington, DC, pp. 217-37.

Yin, R. K. (2009), Applications of case study research (2nd ed.), Thousand Oaks, CA: Sage.