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The role of entrepreneurship in the engineering curriculum

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ABSTRACT: The paper discusses the need to develop by innovative means ways to educate engineers and scientists to become technopreneurial in their outlook. The relationship between entrepreneurship and successful commercialisation is reviewed against the need to achieve a shift in the mindset for the successful delivery of commercial innovation. The paper reviews alternative approaches to the creation of an entrepreneurial culture and the main issues for the engineering curriculum. A more recent approach using multidisciplinary group projects tested at Glasgow Caledonian University, in Glasgow, Scotland, UK, is discussed in detail and the paper concludes that this approach is worthy of further investigation and development. Of particular interest, it is shown that, by setting up a model that creates a stressful environment, students seem to succeed.

INTRODUCTION

As Scotland moves towards the new millennium, considerable attention has been focused on the technology residing in its universities [1]. Concern has been shown that despite a rich base, particularly in the field of opto-electronics and biotechnology, little evidence is seen of technology transferring from the laboratory to the marketplace. Primarily, the question is centred around the fundamental issue of whether engineers and scientists could, in fact, be developed in such a way as to become more entrepreneurial in their outlook and thus develop a mindset more appropriate to the concept of commercialisation. The scale of such a problem cannot be underestimated. Commercialisation goes beyond designing products for minimum cost and demands an opportunistic way of achieving a market orientation, financial acumen and an ability to convince investors that the proposal presented in a business plan is robust enough to be worthy of investment. This is not an easy task as the mindset of the engineer and scientist has invariably been developed in such a way as to focus solely upon the application of scientific and research methodologies.

In this respect, is it possible that engineers are taught by means of an inappropriate nature? Conventional delivery methods range from attendance of lectures, distance learning, short course seminars and so on. Perhaps entrepreneurial engineers need to be taught through less conventional approaches to learning, particularly when learning business skills. Could a new pedagogy provide the mind set shift necessary to achieve the commercialisation result?

The entrepreneur seems to have a number of clearly identifiable characteristics, namely: creativity and innovation, opportunity recognition and evaluation, motivation to excel, tolerance of risk, ambiguity and uncertainty, determination and a strong sense of self leadership [2]. Much of this is difficult to teach and so the entrepreneurial learning process must involve considerable experiential learning whilst also providing a skill and mind set additional to that normally associated with an engineer [3].

Engineers and technologists, it is suggested, rarely cross the line into the commercial arena, and entering the domains of bankers and venture capitalists would not normally be a comfortable experience for either of them. In view of globalisation of economies, it is important that such a clash is avoided through appropriate education both at university level and beyond. Engineering has to sustain society through the delivery of innovative high technology products, systems and services. Government and public support for engineers will only be forthcoming if they are seen to be at the forefront of creative and innovative product generation.

With knowledge now increasingly transient, it is more important to establish a technopreneurial mindset, which can be built into the curriculum as a sustaining and vital driving force for future engineers. This would obviate the classic traditional approach of placing undue emphasis on the knowledge aspects at the expense of factors that can become life-long skills. Thus, educators must be prepared to reappraise what they are actually trying to accomplish and accept the now transient nature of knowledge means they need to consider aspects such as entrepreneurship as a means of achieving the intrinsic motivation that is needed by engineering students.

ENTREPRENEURIAL CULTURE

It is considered helpful to provide a working definition of what this paper means by entrepreneurship, viz:

> *Entrepreneurship is displayed by an individual in an organisation when specific skill and* mind sets

combine to identify, and evaluate opportunities which have the potential to add economic value to products, processes or services and when that individual pursues these opportunities regardless of the resources owned or controlled.

HOW CAN AN ENTREPRENEURIAL ENGINEERING CULTURE BE CREATED?

It is clear that culture is a collective term, which can be identified initially by observing the norms of behaviour in a given context. Therefore, if the desired behaviour is known, then to achieve it the value systems of each member of the collective must be made consistent with it.

It should be noted that values are formed over an individual's lifetime and are established through behavioural interaction with their unique environment and that values formed in early childhood and adulthood are likely to be more firmly embedded in an individual's *mindset* and therefore more difficult to change than those values which develop in later life. Therefore, to create entrepreneurial values, it is important to begin at the earliest point in an individual's development and create a motivational environment that establishes a continuous evolutionary process of revising and reconstructing experiences and which recognises achievement and rewards creativity, innovation and opportunity recognition.

This paper suggests that an appropriate point to begin the process would be at the earliest point at which an individual encounters engineering as a discipline and further suggests that the process evolves through all stages of the engineering curriculum.

IMPORTANT ISSUES FOR THE ENGINEERING CURRICULUM

There are a number of important questions that need to be answered, if entrepreneurial concepts and processes are to enter the engineering education arena, viz:

- Can it be taught - born or made?
- Is there a body of knowledge?
- What does it mean for the curriculum?
    - What goes out?
    - Who will teach it?
    - Where does it fit? [1].

Firstly, the question *Can it be taught?* should be reset to read *How is it taught?* Research has shown that the entrepreneurial gene does not exist [3]. We are a product of our unique environment and therefore exhibit behaviour appropriate to it. Hence to teach entrepreneurship, the learning environment must be arranged to excite, to motivate and to encourage the search for opportunity and to recognise achievement.

Secondly, the body of knowledge has increased dramatically since the first entrepreneurship programme was offered by Harvard Business School in 1946. Today it would be surprising if there were any of the world's leading business schools or universities who did not offer entrepreneurship programmes. Over 35,000 research papers have been listed in one recent publication of an international bibliography [4].

Lastly, and perhaps most importantly for the curriculum is the issue of syllabi overcrowded with science. It is suggested here that this situation must be reviewed, particularly due to the increasingly transient nature of knowledge, and more efficient and effective methods of knowledge transfer identified in order to make way for new processes [5].

Teaching entrepreneurship requires experience and the application of experiential learning. This may be achieved successfully by engaging with practicing entrepreneurs as part of the teaching activity [6]. These engineering entrepreneurs, hereafter known as *technopreneurs*, bring a wealth of benefits not least of which is the confirmation that it can be done and through interaction with the participating students, that they can do it too [7]. One recent approach discussed was the use of a work-based Professional Doctorate as a realistic pathway for the development of high technology entrepreneurship [8].

An alternative method requires a hands-on approach to experiential learning through large and complex group projects [9][10]. There follows a description of work undertaken at Glasgow Caledonian University, Glasgow, Scotland, UK, into this form of activity.

MULTI-DISCIPLINARY GROUP PROJECTS TO ENCOURAGE ENTREPRENEURIAL LEARNING

Teams of approximately eight students have been formed; each team being split into approximately two equally sized groups, one group based in Glasgow (Scotland) and the other based in another university. The second university may equally be from another European country [11]. The Glasgow groups possess the engineering expertise and the remote groups the business expertise. The teams are presented with the task of firstly developing an idea for a product and secondly justifying the idea with an outline manufacturing and marketing plan. All assignments are based around a business scenario and their product should be consistent with the strategy of the business.

One scenario that has been used, the so-called zero scenario, makes them simulate a start-up company. The module operates over 12 weeks and the teams have to very quickly identify their strengths and weaknesses, develop a project plan and assign the main roles/tasks. This stage can take up to four weeks with the students using regular local physical meetings and virtual meetings with the remote group utilising a virtual learning environment. Over the remaining weeks students target the agreed milestones on the project plan adapting these in a dynamic way as necessary. Students are encouraged to take minutes of all their meetings and to have these available to all members of the team on an electronic bulletin board. Staff input during the running of the projects is minimal and takes the form of a number of key supporting lectures and guidance given during the group meetings. Towards the end of the 12-week block, the teams prepare their group report which aims to *sell* their idea to an interested party, eg finance house and provides the evidence base supporting their proposal. The team are also given the opportunity to *sell* their idea via an oral presentation using videoconference tools as appropriate.

ASSESSMENT

The main components comprise: group report, individual report, oral presentation and peer assessment. The group report and group presentation assesses the ability of individuals to

work as a team (ie effective teamwork should be reflected by a high quality group report) and on their ability to communicate their ideas. The individual report is one mechanism by which an individual contribution can be discriminated but perhaps more importantly provides an opportunity for individuals to reflect on their own learning within a team-based activity. This reflection process in itself is thought to enhance and encourage effective learning and is considered to be a major contributor in the development of key life-long learning skills [10].

The student/staff peer assessment enables further discrimination in the assessment of individuals. The peer assessment provided by students encourages them to justify the judgements made. This strengthens the analytical approach taken within the assessment process. The overall mark assigned to an individual is based on an aggregation of reports and presentation marks weighted by attendance and peer assessment. This is considered to be fair and a reliable measure of the attainment of the key learning outcomes by each student.

The findings of this paper are based on the individual assessments. That is, they are based on the analysis provided by the students themselves, as part of their assessment. Temple has evaluated this approach and finds it sufficiently self-consistent to prove useful [12].

FINDINGS ON TEACHING THE MODULE ON THE ENTREPRENEURIAL PROCESS AND ENTREPRENEURIAL SKILLS

Preamble

Students had the opportunity to simulate real life company situations and in so doing, they experienced the difficulties faced by entrepreneurs in handling a team in order to achieve their vision. Working with foreign students gave them access to new and different rationales, points of view, mindsets and priorities. The course allowed the students to experience the challenges of the commercialisation process and marketing research in consequence of which they consolidated existing or acquired new knowledge and skills needed in management, engineering, design, business or entrepreneurship.

More concretely, the learning outcomes ranged from the virtues of brainstorming (as a means to create ideas for products), to the better comprehension of the entrepreneurial process (feasibility studies, business plan, market research, etc). More specifically, the complexity of the new product creation process was amply demonstrated.

Clearly, such a comprehensive approach will not prove faultless and the students appeared to comment freely on both positive and negative aspects of the assignments.

The teaching model currently allows for aspects of behaviour more normally associated with an entrepreneur: for example, by deliberately creating a stressful scenario, the model flies in the face of conventional pedagogy, but the students succeed.

Entrepreneurial behaviour is encouraged from the start. Neither business nor engineering full-time students have ever undertaken such an extensive project and they find it daunting. So daunting, in fact, that most groups flounder for a few weeks until it becomes apparent that a solution must be found, but it is a characteristic of entrepreneurs that they will find ways out of the most intractable problems. Thus the *amorphous front end* of the project engenders panic: *Many of us were taken by surprise on the first day when we were given the assignment sheet and more or less told to* go and get on with it. Schein, however, suggests that such moments of panic stimulate creativity [13].

Teamwork is vital in modem industry and indeed is one of the principle objectives of the module. Entrepreneurs have a skill to surround themselves with teams of able and supportive individuals. The entrepreneur can instinctively detect potential dysfunctionality and forestall it. In truth, this is not generally found to be the case for student teams. It is much more likely that they recognise problems and their solutions after the event. They say, *I know how to do it better next time.*

Much has been written on the subject of teams in education [14]. Literature is also available on this style of project [15][16]. Even small teams, if separated by distance, may not function well. For example, a team member that does not attend a local meeting may be taken to one side and the problem addressed, but a lack of response to an e-mail is capable of more serious consequences because it engenders a lack of trust. Repeated poor responses quickly lead to dysfunctionality: *When the project started I found it exciting, challenging and therefore had a lot of enthusiasm for it,* but as tasks were not completed on time or information took longer than anticipated, the initial enthusiasm waned. *The fact that one individual failed to do a task sometimes had a knock-on effect and prevented others from carrying out their tasks.* To an extent this behavioural pattern is found within commercial teams, but they have more immediate forms of redress for poor performance. Students have no access to such draconian measures. However, proximity to the end of the project forces groups to pull together: those that were working well; to work more intensely and those dysfunctional groups; to develop some form of integration. One stated:

> *The mid-term holiday was a milestone for the reason it reflected the moral and motivation at a low ebb. Return to the module created a knee-jerk reaction … it was at this point that the group worked well and efficiently.*

Communication at a Distance

It is worth noting that international projects put additional strains on teamworking through the lack of eyeball contact and the language barrier. Under these circumstances, small differences can escalate and threaten the whole project. Dysfunctional groups suffer the most:

> *The time when it did start to hit a few snags was when the business students* [at another university] *decided that the product was unmarketable. From our group's point of view, this just seemed like they were being too laid back, as they* [had] *agreed that our first product was ideal and that they would have no foreseeable problems when marketing it.*

Creativity, Innovation and Opportunity

By asking teams to identify new products, the students were being asked to be creative. They used brainstorming techniques to identify a product, for example:

> *Initially various ideas were put up for consideration. It didn't matter how silly they appeared; they were all discussed. Sometimes the most stupid appearing idea can evolve into a great one or the simplest one is the one that fires the imagination of the public.*

The aim was to identify a product that would be interesting to develop, would have a chance of being a commercial success and more pragmatically, would afford them the best chance of a good mark. Such an approach was found to be very interesting since it opened their eyes to a whole new process of how to decide on a product - mainly through brainstorming sessions and weighting tables - before carrying out the market research.

The exercise itself is usually entertaining but not always very creative. There is often, however, long-term learning in so far as students appreciate more fully what it takes to create a so-called new idea.

> *Now I view annoyances in everyday life with a different perspective. Could I improve this? Could I design that annoying thing out? Would that sell? These questions pop in to my head, which never dawned on me before.*

It became clear to them that an entrepreneur has to wear many hats when starting up a company, to survive and then grow. They were sensitised to opportunity.

Evaluation

It certainly became quite clear that the students acquired a good appreciation of the processes:

> *I assumed the entrepreneurial process was mainly driven by luck and during the project, have learned that the process may be helped by luck, but is driven by planning and detailed analysis. To complete the project, a lot of information about available alternatives, existing products and similar designs in other fields was gathered and then discussed to determine its relevance.*

The course put stress on the process of evolution that takes place before a product concept is perfected:

> *We began the project with numerous ideas for products all of which seemed to be good ideas and narrowed it down to one that was feasible. This allowed me to appreciate the process that must be undertaken to allow a business to succeed.*

The Cross-disciplinary Nature of the Activity

The market research and feasibility study was considered by the engineers as one of the most useful outcomes of the course; several statements made include:

- *The market analysis seems to be a pretty innocent affair until you really get into it. It's not just about getting a few questionnaires filled in and hope you get the right result. The questionnaire itself must be unbiased and contain more questions to aid the marketing and pricing strategy, if you get that far. It could also include questions to give an indication of which product features are most desirable to assist in the product specification. This is a crucial step; as if you get this wrong then people could lose a lot of money. Getting it right though is still no guarantee of success.*
- *…the Liege group carried out most of feasibility but by reading their information an appreciation of the feasibility was gained.* [It] *presented our group with a challenge to reduce our initial product cost, … achieved by a redesign, which did not impact on the product specification.*

The financial aspects of a project met with the following statements:

- *I was not very financially aware but now appreciate a lot of factors that are involved in the finance and marketing of a product.*
- *The costing analysis* [was] *mostly carried out by* [the business students and] *although it did appear quite late in the day,* [it] *helped me understand much more the whole concept of profit margins, break even analysis and also projecting figures in order to achieve a decent understanding of how the product would hopefully take off in the next 2-3 years from initial production.*

In particular, engineering students had better comprehension of some common concepts such as the business plan: *This was a term* [business plan] *of which I had heard before but had relatively little understanding of its contents.* Yet even the business students found the reality of this approach beneficial since they had never prepared so comprehensive a document. They had not appreciated how much they relied on engineering information; an aspect not usually considered in a business programme.

CONCLUSION

The activities that had to be undertaken did require action and action is fundamental to the entrepreneurial experience [2]. This is very positive since they would have had to use the entrepreneurial behaviours as suggested by Timmons to complete the module successfully. Although, at this stage, it the extent of the behaviour they employed cannot be specified, nor specifically who employed them within the groups, it can be concluded that they would have been present during the process of the project.

The teaching model includes aspects of behaviour more normally associated with an entrepreneur, namely: creativity, commitment, determination, leadership, tolerance of uncertainty and the need for self-motivation. By deliberately creating a stressful scenario, the model flies in the face of conventional pedagogy, but the students succeed. In the real world, success is everything.

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edited by Zenon J. Pudlowski & Romuald Cwilewicz

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