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Developing Skills in Creativity and Innovation Through New Product Design

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ABSTRACT

Based on a review of economic theory and associated papers, the generally accepted five forces of national economic growth are identified. The fifth and most important of these is recognised as innovation, and through further analysis innovation is shown to be primarily dependant on creativity skills and new product (process or system) design. This is tied in with the second identified force which is improvement in the quality of labour through education, training and experience, and there is general acceptance that it is only in this area of education that government can exert any significant influence in a free market.

The paper then describes the principles and practice underpinning a final year MEng module on Innovation, and outlines the radical and innovative approach taken to teaching and learning on this module through close collaboration with industry and through a largely student generated taught syllabus. The accompany conference presentation is an overview of an industry generated (client brief) team project which acts a vehicle for teaching and learning on the Innovation Module.

I. Theoretical Justification for the Innovation Module

The final two years of the five-year MEng programme is run jointly by the German Universities in Augsburg and Kempten and the University of Ulster. Students participating in the programme can gain the UK MEng degree and the German DipEng. Statistically there are 30 students per year on the Innovation Module with 80% coming from the German universities and 20% from The University of Ulster.

It is by circumstances of fate that the two nations represented on the MEng programme and the Innovation Module are British and German because it is these nations

who were at the forefront of innovation in Europe throughout the nineteenth and twentieth centuries. A well researched essay on the interpretations of the industrial revolution in Britain (1) and in particular the role of invention and innovation, demonstrates that there are lessons to be learnt that should inform today's economists and policy makers. The paper argues that the British dominance in the early (or first) industrial revolution has its roots in technological inventions based on scientific discovery. The scientific discoveries were a consequence of the superior British education system at that time. However by the late nineteenth century and into the early twentieth century innovation and diffusion had come to the fore. The British education system did not adapt and Britain lost competitiveness. By 1908 Germany had overtaken Britain as the leading industrial nation in Europe (2), and by the outbreak of the First World War Britain depended on Germany for many of its consumer goods. An examination of the numbers of university students in each country in 1913 give some indication of the scale of the problem, Britain had 9000 university students and Germany 60,000. Perhaps more importantly Britain produced 350 graduates in all branches of science, technology and mathematics and Germany 3000 graduates in engineering alone. Clearly British policy and had not recognised the paradigm shift from scientific discovery and invention to innovation and diffusion. At this time innovations were largely the result of new technology based largely on the discipline of engineering which is also a product design discipline (3). It was actually Schumpeter who analysed the technical change process or the process of "creative destruction" as comprising three distinct phases of invention, innovation and diffusion (4).

Schumpeter (5) and Kondratief (6) are individuals who have pioneered the idea of economic cycles. According to Kondratief the waves are caused by periods of excess,

financed by perceived wealth and fuelled by debt, followed by long periods of readjustment. Our current recession (depression) fits Kondratief's description of a cycle and his approximately 50 year timeframe. Each cycle can be seen to have a prime mover for innovation, for example in the nineteenth century it was mechanisation of manual operations. The early twentieth century saw the introduction of automation followed later in the twentieth century by computerisation. What will drive the next wave?

In the twentieth century the forces that drive economic growth were recognised as (7):

1. Additional labour
2. Improved quality of labour through education, training and experience
3. Added capital through investment
4. The rate of productivity of capital
5. Real Cost Reduction

The second element is where educationalists come into the picture provided of course we are producing people with appropriate knowledge and skills. There is a general consensus that it is in the fifth element that the greatest improvements can be made. This element is historically considered "vague" by economists, covering elements such as technical advance, changes in total factory productivity, shift of the production function and real cost reduction (7). The Harberger Triangles (8) attempt to identify the deadweight loss to society caused by intervention to the perfect market economy through devices such as taxes, government regulations, monopolistic practices and various other market distortions. However these did not fully explain the observed growth in GDP that is better than economic theories can predict (9). However more recently this "vague" element is being recognised for what it really is, innovation, and it is not steady state, there is "churning" (10) taking place in society whereby business entities become more efficient or productive, new businesses are formed and inefficient ones disappear. The net result is a growth in the economy with associated increase in labour skills, increased return on investment and real cost reduction. Clearly if we can recognise the nature of this fifth element, then through analysis we can arrive at the education, training, skills and experience we need to impart to students, and through intervention in the education and training systems, ensure individuals are equipped to contribute to the productivity of their employer and the GDP of the economy as a whole, and not let society become victims of progress elsewhere as the British did at the beginning of the twentieth century.

II. What Is Innovation

The fifth element in measuring growth is increasingly recognised as innovation, which rises the question "What is Innovation?" This is also a question raised by the US Advisory Committee on The Measurement of Innovation in a report to The Secretary of Commerce (9). Their conclusion was that innovation is "The design, invention, development and/or implementation of new or altered products, services, processes, systems, organisational structures or business models for the purpose of creating new value for customers and financial returns for the firm". It is more simply stated as "The commercialisation of new ideas" (10). Innovation is difficult to define (10, 11), because it is not a verbal activity but a non-verbal activity. Verbal activities can be defined but non-verbal activities such as design are impossible to define except within a specific scope.

Although innovation cannot be defined it can be understood (11) in terms of:

1. **Observation**, to learn to recognize examples of real creativity and innovation in ones own discipline
2. **Knowledge, Cognitive and Practical skills** both general and discipline specific
3. **The Creative and Innovative Process** in generic terms and as it relates to ones own discipline
4. **Practice** makes perfect, through work on projects that are real and require creative and innovative solutions

Above all innovation is a creativity activity generating new, unique and original solutions in response to need, want and opportunity. The really radical innovations are those that generate a solution to a latent need or want. This implies that innovation is a process that begins with the process of invention (11), often associated with scientific discovery, and the narrow conclusion reached that true innovation is the commercialisation of a scientific discovery. The process of invention is a creative process generally comprising five steps (12):

1. Problem identification
2. Information gathering
3. Act of insight
4. Eureka
5. Refinement

The act of insight is normally associated with associative thinking and the five elements of associative thinking are:

1. Technology transfer
2. Adaption
3. Combination

4. Analogy
5. Chance

Chance, sometimes omitted from the list, favours the prepared mind, and suggests that experience and knowledge combined with an open and searching mind are more likely to lead to a unique and original idea as a basis for a solution to the problem in hand.

Examining the act of insight phase on the basis of associative thinking (cognitive skill) demonstrates that ideas that lead to solutions to a problem are much more likely in the context of design than they are in the context of scientific discovery. The process of invention, frequently called the creative process, is a prerequisite for or at least an integral part of the process of innovation. The process of innovation has been described as the process of design or the business process preceded by the process of invention (13). The process of invention itself is shown to be based on design. It is therefore reasonable to argue that the process of innovation is a creative process of design or a creative design process combined with a creative design based business process.

If the fifth element of economic growth is innovation, and this innovation is fundamentally creativity based on design, then in terms of element two of the factors on which economic growth is usually based (7), this tells us that education, training and experience should embrace creativity and innovation and in the context of the students discipline. This means identifying an appropriate innovation process, key skills, and creating the environment for students to engage in creative and innovative activity in the context of their discipline.

III. The MEng Innovation Module

The MEng innovation module is based on the approach outlined above and developed in previous papers published by the author. The argument is that innovation cannot be defined but rather understood in relation to ones own discipline by consideration of four elements:

1. **Observation:** Studying products (processes and systems) with a view to understanding what merits recognition as innovation and what does not.
2. **Knowledge, Cognitive and Practical skills:** Identifying those necessary for successful innovation
3. **The Creative and Innovative Process:** Knowing and understanding the processes that led to successful innovation
4. **Practice:** Learning through participation in innovation activity.

It follows that innovation teaching and learning should be based on these four pillars.

By year 5 of the MEng programme students have received their subject specific knowledge, education and some training. Innovation course objectives are to create a learning environment whereby they can recognise innovation, identify and practice key skills, identify and develop a relevant process of innovation, and learn through experience gained through participation in a live industry based innovation activity. The teaching and learning programme is divided up into twelve one day sessions, delivered on a weekly basis, and generally structured as follows:

1. AM: Semi-structured on-line exercises intended to help students identify innovations in their own discipline and report back on their findings to the class as a whole.
1. PM: Creativity classes where the emphasis is on semi-structured, team based user centred design activities, followed by team based presentations to the class as a whole.
2. AM: Teaching and learning are based on a real live industrial project requiring innovation. The problem is presented to the class by senior members of the participating company. The presentation is followed by an open question/discussion time between the company representatives present and the class.
2. PM: The afternoon is left free for the students to form their own four person groups ideally with the mix of skills and expertise to solve the problem presented. They have to analyse the nature of the problem, the knowledge and skills inherent in the class, and draw up their teaching and learning programme for the remaining ten weeks of the module. In generating their solution the students develop their own process of innovation, develop discipline specific key skills, and engage in innovation activity.
3. Students are taken to company premises and to learn more about the company, the skills and resources available to it, more about the business in which the company operates, and to ask questions of anyone in the company.
- 4-11 In the following weeks the students are free to request information from the company, which is made available on the same basis as information is made available to company employees. The

students are free to visit the company by appointment to ascertain any other information or knowledge they consider relevant to their project.

Throughout this period at prescribed intervals of one and two weeks, students submit on-line confidential team and individual reports to the academic. The team report is action minutes based on weekly team meeting to review progress over the past week and delegate tasks for the following week. The individual confidential report is based on the contribution each team member has made to the team over the past two weeks and also the contribution made during attendance at the weekly team management meetings. Each team member scores other members of the team; the objective is to identify the relative contribution each member is making to the project.

12. An industry expert provides a lecture on presentation skills followed by an open ended question and answer session

Over the years this innovation module has been running, it is estimated that approximately half of the projects have been commercialised.

IV. Assessment

At the end of the module each team makes a presentation to industrial representatives. The presentation normally lasts for one hour, with forty minutes for presentation and twenty minutes for questions. Each team member receives individual marks for their contribution to the presentation. Over-riding considerations are their integration within the team and their personal ability at communication. The equally weighted assessment criteria are quality of presentation material, delivery, mastery of topic, and response to questioning.

The project report is marked out of 80. The academic awards absolute marks for each report based on predetermined assessment criteria, and each year this is influenced by the nature of the innovation topic. The relative marks awarded to each student based on the fortnightly confidential reports are tallied, and these marks are used to adjust the absolute project report mark to reflect the relative contribution of each student to their project. The formula used is:

$$\frac{Sr}{Gra} Ra = Sa$$

Where:

Sr = relative mark awarded to each student by peers

Gra = group relative average mark

Ra = absolute mark awarded for the report

Sa = absolute mark for the student

For example, if relative marks awarded are 50, 60, 70 and 80 across each student in a group of four, the average mark is 65. If the absolute mark awarded for the report is 60, the absolute report marks for the students are 46.15, 55.38, 64.62 and 73.85 respectively.

Added to these are the individual presentation marks (Table 1) to give the final individual student mark for the Innovation Module.

V. MEng Vs Dip Ing Design

The UK MEng has its roots in the traditional academic system of education. In this context engineering itself grew out of science in the eighteenth century, and science is focussed on the scientific method and the means by which scientific knowledge is generated (understanding the created environment). It follows that in the university context engineering and engineering design is primarily concerned with mathematical articulation of scientific theories to arrive at “what could be” output (14).

In Germany and elsewhere in Europe in the 1960’s it was recognised there was a shortage of engineers to service the needs of industry. To address the shortage the German Fachhochschulern system was formed in the 1970’s, whereby technological or production engineers could be educated in three or four years. The aim was to produce engineers with practical knowledge and students graduated with the award of Dip Eng (FH). Engineers graduating under this system were focussed on applied science, technology, know-how and “what will be”(15).

Accepting that design is at the heart of engineering, and hence studying the core principles underpinning engineering design, it is possible to ascertain how skills in creativity and innovation can be developed through the model described in this paper:

1. Fundamental design concepts: these include principles of operation and configuration. These are more likely to be the result of creative thinking leading to innovation.
2. Criteria and specification: Best results will come from application of user centred design, inclusive design and empathetic design techniques.

3. Theoretical tools: Based on mathematical articulation of scientific theories.
4. Quantitative data: From published tables, investigative research and secondary research techniques.
5. Practical considerations: Based on known materials and production technologies.

6. Design tools and techniques: the result of training and experience

By combining the Fachhochschulern and university systems of engineering education in the context of new product design activity, and adopting the approach to innovation education outlined in this paper, students can develop skills in creativity and innovation across the totality of engineering design practice.

	Presentation (5)	Delivery (5)	Mastery of Topic (5)	Response to questioning (5)	Total for presentation (20)	Report Marks (80)	Total (100)
Student One	2.5	3	2	2	9.5	46.15	56
Student Two	3	4	3	3	13	55.38	68
Student Three	3	4	2	4	13	64.62	78
Student Four	5	3	3	4	14	73.85	88

Table 1

V. Conclusions:

GDP and economic growth are shown to depend primarily on (new product) innovation. In addition the only element of the five forces that drive economic growth where intervention can occur with meaningful benefit is to improve the quality of labour through education, training and experience. It follows that the process of innovation presented here in and engineering design context, is a “universal” approach that can be adapted for virtually any discipline, and can be used to drive innovation forward to the benefit of the community and the economy.

The case study and the supporting contrast of the university and Fachhochschulern systems of education serve to demonstrate that scientific knowledge of the created environment, technological knowledge and know-how on manipulating the created environment, combined through the philosophy of creativity in the context of design, provide an ideal environment for students to learn and practice innovation.

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