

ENTREPRENEURSHIP & INNOVATION IN MATERIALS ENGINEERING

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Abstract: Having developed a module on Creativity, Innovation, Enterprise and Ethics that reflects the continuous drive to educate the all round engineers highly sought after by employers and run it over nine years, we have collected enough evidence on both the validity of such efforts as well as their effectiveness in achieving their goals. This paper summarises the cumulative experiences of developing and running this module over the years and discusses possible future directions.

Keywords; engineering education, creativity, innovation, enterprise, ethics, personal development.

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1. INTRODUCTION

1.1 Course concept

The course, originally denoted as module MAT388 'Creativity, Innovation & Entrepreneurship' evolved out of the perceived need to close a knowledge gap that appeared to exist in our engineering materials graduates regarding to the commercial side of engineering design, Kapranos (2008). Materials are what designers use to create their various artefacts and it would be true to say that most of the dramatic developments in engineering materials over the last century have been the result of scientific research. However, it would be equally true to say that for every pound spent on science driven research, over the same period of time, a much larger proportion was spent on research driven by specific market needs.

Figure 1 shows an adapted simplified analysis of the various drivers behind product design proposed by Fields et al (2001) that despite its simplification serves as the basis for the perceived need for creating the above module. Of course it was felt that there is another important point the module should address in order to complete the development of our graduates was the development of the 'self'. As engineers and scientists they must be aware that apart of the knowledge and expertise they will take with them into their chosen professions, they will also inevitably carry with them their personalities, their values, beliefs and attitudes and these can have a major effect not only on their design approach but on the correct execution of their professional duties. For that reason, ethics in scientific research and science were included as

part of the module and hence the slightly final long winded title: ‘Creativity, Innovation, Entrepreneurship and Ethics’.

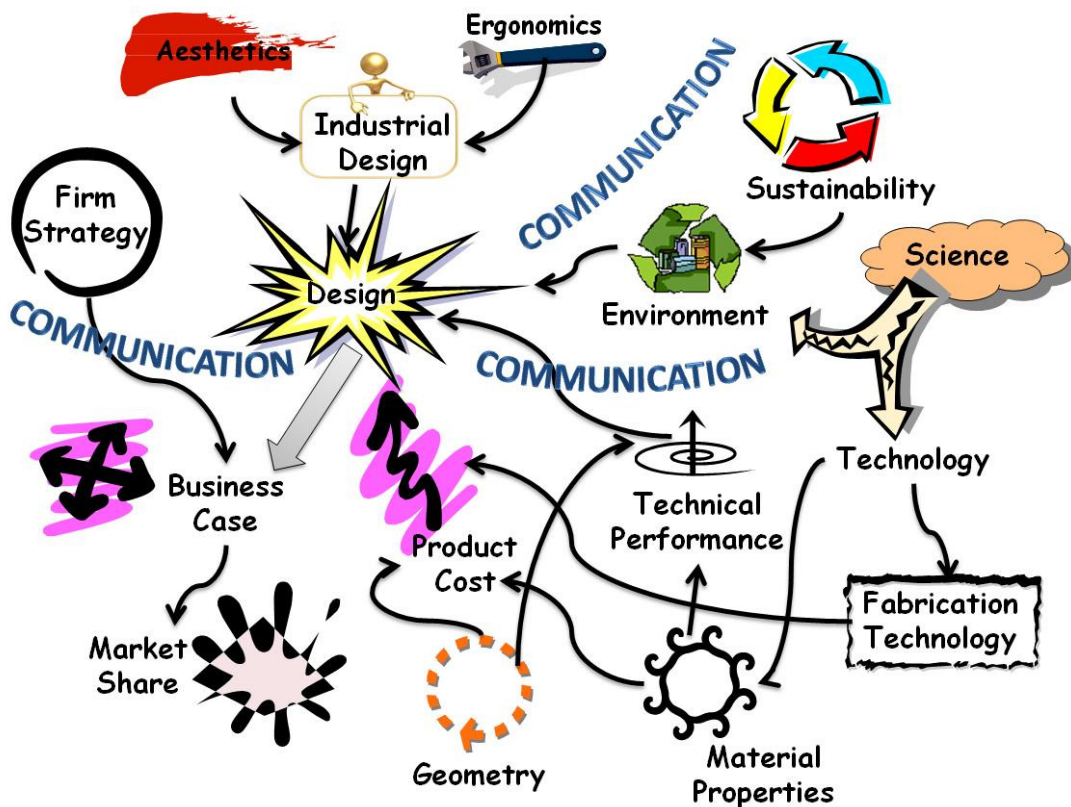


Figure 1 Driving forces that influence product design, including the very essential communication between people [adapted from Fields et al (2001)]

1.2 Course development

The module has run over nine years with continuous modifications and improvements both as far as content and delivery were concerned. The need of realization by the students of the complexity involved in engineering decision making due to the multiplicity of objectives and of course materials available to them required the introduction of topics such as Decision making, Behaviour in Organizations, Leadership, Motivation, Conflict, Negotiation, and Project Planning. In addition, Quality Control, TQM and Project Appraisal techniques also found their way in becoming part of the module together with the basics of financial and management accounting and costing.

Of course, immersing the engineering students in such concepts is neither easy or popular with all of them and care has been taken to embed these topics through a combination of group case studies and the use of external lecturers that can bring them into focus through industrial applications or professional expertise, e.g. use of a Pattern Attorney, Special Projects Manager, Director of Policy Planning, etc.

Although the changes in content have fluctuated within certain boundaries limited by the curriculum, the teaching methodology has been more flexible allowing the transformation of the module from one of a ‘lecture heavy’ mode to one of ‘inquiry based learning’, giving students

much more active participation in their learning experience, as well as empowering them to broaden their communication, group work and presentational skills as part of the continuous assessment format of evaluation. The suitability of inquiry based learning has been debated by many and Perrenet et al (2000) give a good summary of the debate.

The course is based around lectures on the themes outlined above supported by short class problems/cases interspersed throughout the module. The assessment is in continuous format and it is based on mini-case studies, for example where the students have been given some 'seed funds' and have to go away and increase their capital over a period of a week, or the development of a business plan in prescribed markets, group presentations and a final individual portfolio where each student expands on their own particular take of the complete module. The structure and presentation of the individual portfolio is purposely kept flexible in order to bring out the creative aspects of the students as well as their own interpretation of the subject matter discussed over the series of lectures and discussion sessions.

Although this approach reflects the creativity ethos of the module, it has the drawback of consistency in assessing the individual contributions. A balance has been struck by setting out the various areas that students must address in their portfolios whilst still providing them with individual choice of how it is done; 'show them the mountain to climb without specifying how they actually do so'. Admittedly the assessment system is far from perfect but in the main allows both individual creativity and group performance to be looked at.

The group experience in inquiry based learning of the students is what they seem to have appreciated more than anything in this module. Being thrown into a 'money-making' exercise from early on and finding out how to do it themselves successfully and within legal restrictions, quickly brought up a number of issues that were then looked in more detail and discussed in class.

Furthermore, the continuous use of group work with all its associated issues acted as a focus, bringing to the fore such topics as motivation, conflict, negotiation, leadership, decision making, for class discussion. This direct relationship of coupling personal experience, derived through the group process and associated information handed out in class became a powerful learning tool; so much so that it has already been planned that every topic covered in future modules will be based on group cases supported by handouts and short Powerpoint presentations.

Finally, the use of 'experts' is another learning tool that has been used successfully and will continue to be part of this module. Students react positively in seeing real applications of the knowledge being discussed in class delivered by persons who are experts in a particular field, be it a patent attorney discussing IP issues of innovations or a Psychologist discussing behaviour in Organizations.

1.3 Student responses in their own words

Of course it would be easy to sing the praises of ones personal work but the voices that matter should be those of the students themselves, including voices of dissent or dissatisfaction:

'This module is a welcomed break from the usual engineering subjects...it brings a new perspective about the world of business, how to manage myself and deal with others...the knowledge gained will be carried into my working life and beyond'

'The module covered not only creativity, innovation and enterprise but psychology, philosophy and personal character capabilities.... I now have a better understanding of myself, human nature, human behaviour, the way people think, and how to deal with people...'

'Although the module may have been necessary for the more narrow minded engineers, I never find myself stuck for ideas or inspiration...I found the management terms and strategies totally uninteresting and hugely patronising...'

'I especially enjoyed the good atmosphere and diversity of the class...the group projects and presentations were a wonderful experience...'

'I feel I have gained something from this module I couldn't have gained from others...I feel I have become a better person and engineer in some ways...I think the module has made us all better engineers...'

'I know one thing that I know nothing, Socrates...once you embrace this mind set you are free to learn all you could possibly learn...realising you know nothing allows you to see things for the first time, with an open mind, no pretences, nothing taken for granted, nothing is too obvious any longer...'

'It is difficult to produce a module that will satisfy every student...there were parts of the module I would like to see removed, the statistics for instance, however other students may find them relevant, interesting and important...'

'I thought the group exercises were a great learning experience because of what they involved, working in groups, finding things for ourselves and standing up to present our cases...'

'The whole series of lectures has given me much cause for thought...the lectures on ethics were excellent...'

Good points: well rounded module, interesting topics, subjects covered useful for the future, generated lots of enthusiasm, especially the group work and presentations, relaxed lecturing style helped the learning experience, good range of speakers, clear and straight forward assignments...

Bad points: Few irrelevant topics for engineers, some speakers had poor communication skills...

Recommendations for the future: more group work, more mini-projects in class.'

'I was pleasantly surprised with the first in this series of lectures...as opposed to numerous other lectures the atmosphere was much more relaxed and opened the floor to a different type of thinking rather than just plain note taking and learning facts...'

'This module turned out to be an interesting module; it has made me think about myself and what I want from my career...it has also helped me to identify some of the areas I need to work on to improve myself...'

'This module has been a rewarding experience...I hope it will remain the staple of the 3rd and 4th year undergraduate course and with its enthusiasm and applied innovation continue to inspire students to greater things...'

'I have enjoyed creating the personal portfolio...I have put thought in every single page to make it interesting and used my creativity to present it in a different way...I hope the readers can have as much fun reading it as I had making it...'

'My favourite guest lecturer was on communication...a priceless lesson...'

'I found the guest lecturers unnecessary and dull with one exception...the one on transactional analysis...truly inspiring... I even bought the book today...'

'I approached this portfolio in a manner which maintains the overall theme and vibe in the class room; colourful and energetic...'

'This module proved to be a great journey...I greatly enjoyed the course...don't worry about the destination just enjoy the travelling, take life as it comes...an excellent moral that I intend to follow...'

'The personal portfolio is creative for me because it is representative of my personality and has been created by my inner self...similarities between myself and the portfolio: well organised, thorough, full of information, unique and full of positivity...'

'Creativity cards...an excellent idea that I will definitely be using in the future...'

'The group tasks became the most enjoyable and most challenging aspect of the module...they enabled me to apply what I learned in the lectures...perhaps the most important lesson is that there is more to management than meets the eye...'

1.4 Worried colleagues & Negotiations

Once again, trying to live up to some basic tenets of good teaching, i.e. 'if we want students to learn we must capture their attention', 'the more you can provide them with a framework to interpret the material being taught, the easier they will understand new ideas', 'don't overload the system', and having gone down the unpredictable road of power sharing with the students, there were occasions that colleagues and sometimes students were left bemused by the slightly unorthodox, even chaotic proceedings.

In addition, having chosen that the module would be continually assessed, with no conventional written examination at the end of it, created both challenges and opportunities to try different things in motivating the students, i.e. competition between groups, prizes as well as individual portfolios relating their experience of the module in their own words.

What follows are examples of communications between the module leader and various colleagues and students during the latest module completed in December 2009.

Dear Plato

I have seen the surveys for lunch deliveries to staff produced by students which are, I think, an exercise for your module. They are then going on to deliver lunches they have made for a week. Forgive the obvious question, but has someone looked to see whether there are any Health and Safety issues connected with this - does this activity come within the HSE rules for selling food since they are being paid for it.

Yours, John

Dear Dr Kapranos

I've just had a visit from some students on a money making project from one of your courses? Before I parted with my cash I wanted to check that the proceeds were going somewhere other than yours or the students pockets! Which is what the students seemed to think? Have you got a charity lined up?

Cheers, Colin

Dear Colin,

This is a group project on a money making scheme as part of the Innovation & enterprise part of the module.

Originally I had in mind a charity. However, as I have already parted with £40 of my own cash which I used as 'seed funds' for the group exercise, I hope that I will get my own money back (although not guaranteed) and then discuss with the students what to do with any profits if there are any.

The module also includes ethics so we will see what happens.

Regards, Plato

Good luck.

Ethics and business? That sounds very challenging!

Colin

Hi Plato,

At Staff-Student committee on Weds the 3rd year BME rep raised a couple of issues regarding MAT388. Firstly there were some complaints about the perceived workload and secondly there

were some issues regarding guidance as to what was required for the CA submission. The first issue is probably just down to timetabling, with your module competing with BME projects, MAT372 'Group Projects in Bioengineering' and MEC305 'Engineering Management' for their time in Semester 1. Flicking through the timetables of the various cohorts who take your module it does certainly seem that BME have quite a crowded timetable, with 12 free slots per week compared with between 19 and 28 for some others. The only other cohort with a similar lecture load is BEng Aerospace Engineering, with 13 free slots per week. I haven't heard of any issues from this cohort but then there are only two students as against 19 from BME. Obviously we don't actually need to change anything if you don't think it appropriate but we need to show that it has at least been considered.

Hi Plato,

after discussing the sponsorship of your presentations with the team and finding out from Omolade what last year's winners received, a £10 voucher, we are happy to match this and provide the funds for a £10 Amazon voucher for each individual in the winning team.

As you will not know how many people are in the winning team until on the day it would be best for us to transfer the funds once the winners have been announced so you can purchase the vouchers.

University of Sheffield Enterprise has certain targets to hit, two of which include business plans developed and individuals advised and engaged. Therefore, are we able to take copies of the businesses plans produced by the teams? All information will be kept confidential! We also need to evidence the people involved in the activity we are funding, this would simply involve the students signing in on a sheet we produce. Tracey and I would get the students to sign this so there is no additional work for you.

Does this sound OK to you?

Many Thanks, Sarah

Hi Plato,

Yes, we are happy to sponsor the winners at £20 each. Are we able to have copies of the business plans?

Many Thanks, Sarah

Hi Plato,

Thank you for allowing Tracey and I to judge the presentations on Friday, we really enjoyed listening to the great ideas and were very impressed.

I have attached a couple of photos for you, although they are not the best quality. As we discussed, it would be great if you could either pop copies of the business plans on the internal post or I will call over and collect them. Thanks

Sarah

Dear Dr Kapranos,

we are very pleased that we won today, Rahma told us that one of judges suggested that we could apply for funds to actually start up such a business. I personally think this would be a great opportunity, and would be fantastic to have it in our CV. I was wondering if you can help us to get in contact with her, or advice us in this matter.

Thanks for your great lectures this semester

Best Regards, Atra Malayeri

Excellent, if any of the groups want to take their ideas further put them in touch with us. Have a great Christmas.

Sarah

2. DISCUSSION

2.1 General comments

Teaching a module which in the majority has a non-technical content to students of engineering is an interesting challenge and this challenge is especially enhanced when the students are on their final year of studies. The thinking for positioning such a module in the later years of undergraduate studies was based on the fact that the students have to develop a thorough understanding of the scientific/technical aspects of their chosen field of expertise before they could start making the appropriate associations with extraneous subjects such as management, innovation, enterprise and ethics. However, this logic has a number of drawbacks, one is that these subjects, as can clearly be inferred from Figure 1, are not extraneous but in fact they are an integral part of engineering design, and of course it goes without saying that exciting design that will help society through the various predicaments we are currently facing as a species will only come through creativity and innovation. Another drawback is that if the students are allowed to arrive towards the last year of their studies without even the rudiments of awareness of these topics, then it will require a great amount of creativity in the part of the teachers to first engage the students and then work through the various mental mind sets that have been formed; as can be seen in some of the examples of '*students in their own words*', above. Furthermore we are making the assumption that first year undergraduates are not capable of making the necessary connections early on in their course.

It appears to me that the educators are following their own mind sets in making these assumptions and it would be more appropriate if we expect our young undergraduates to be part of the solution to the problems of sustainability, they must learn early on how to think systemically and consider the whole rather than only the sum of its parts; it is not a case of either or is a case of both used in balance as appropriate. There are conflicting issues there but these have to be emphasised and resolved early on rather than left to be dealt with as an after thought. The work of the engineers is in continuous tension in creating the things of tomorrow with the technology of today, if not the technology of the past. There is a balance to be had between working with what is within our grasp and things that are beyond our reach. There is always a risk involved when you reach out further than your grasp but risk has always been part and parcel of engineering design. Engineers have always taken risks but they like to think that these risks are based on knowledge and probabilities and as such there will always be faced with failures of their creations. However, it is very important that they learn from their failures and use their failed experiences as guides for future decisions as technological evolution is based on conscious choice rather than natural selection.

2.2 Comments on module MAT388

Material Engineers must be knowledgeable of the basic facts of their profession. However, any profession has a number of further characteristics associated with it:

- Requires specialized knowledge
- Requires considerable preparation in skills, methods and principles
- Requires maintenance of high standards of achievement and conduct
- Requires engaging in life long learning and public service

Here is an example taken from the Code of Conduct 1989, The Institute of Materials (UK).

Public Interest: Members shall do all in their power to ensure that their professional activities in no way put at risk the health, safety or welfare of any person or expose property to the risk of destruction or serious damage. In addition, members shall have due regard for the need to protect working and living environments and the need to ensure efficient use of natural raw materials, reserves and resources.

So clearly our graduate engineers must supplement their specialized learning with other skills, communication being a very important example. They have to be aware that in the final analysis in whatever we do for a living we will deal with people; it will always be us and them! Therefore, a good starting point would be to know who we are, what makes us tick, what we believe in. This personal knowledge is very important if we are to follow the code of ethics of our chosen profession. There were always ethical conflicts and there will continue to be so we must be aware of where do we stand as a person in relation to the multitude of issues that will face us and challenge us as engineers.

As it can be seen from the points raised by the students themselves, it is impossible that any module we create will be equally interesting to all, as educators we can only do so much and no more. However, if we accept as a model that education is not like transferring water into an empty vessel but rather the analogy of going on a journey, then we can see that this module has gone a long way down the road of making the students part of the exploration, setting ports of call as targets without marking out the exact route to be taken in the hope that the students both enjoy the journey and gather a lot of knowledge on their way.

As a module on creativity amongst others, I strongly emphasise the aspect of *'fun'* as an antidote to stagnation of ideas which comes from our fears; especially for students the fear to be heard and the fear to be seen as being different. In future, therefore, there will be continuation of the parts enjoyed by the students, such as group work and case studies, and re-structuring of the parts they found harder to engage with in more inquiry based learning approaches.

In closing, I would like to think that the module goes some way towards the vision of the Renaissance Engineer by Dahms (2001): *'Broad minded, ethically and ecologically responsible agent of social and material change towards a socially just and ecologically sustainable world'*

3. REFERENCES

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