

Student learning on non-traditional modules on traditional courses

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Abstract

Science and engineering students arriving at university tend to be numerate and able to deal with technical problems well. However, their creative and descriptive skills are often poorly exercised. Most of the subjects taught at first year reinforce this approach. Graduate engineers however need to be creative and literate independent learners.

At the University of Sheffield two modules for first semester students try to encourage them to be more descriptive and creative within an engineering context. The first of these allows the students to use any form of output to allow them to express themselves and the second gets them to write a summary of a paper to get them to assimilate information and to allow them to write succinctly.

Initially, students can find these open-ended assessments very difficult. Ultimately, however, most engage with the exercises in a mature way. The effects of this effort mean that they are more confident self learners with an understanding that there are many ways to produce good quality outcomes. It also allows them to understand that creativity is an important facet of engineering, but one that must be built on an understanding of the technical underpinnings of the subject.

Introduction

Straight from school, engineering students tend to have studied subjects which require the production of the “correct answer” (Lithgow and Abachi, 2006). These students arrive with certain expectations and with a skills set that has been honed to get them through their previous hurdles (A Levels or equivalent). Experience has shown that this training appears to have encouraged students to try to work out what the teacher (or at university, the lecturer) wants (Lowe et al, 2003).

According to Kesten (1987), "Independent Learning is that learning in which the learner, in conjunction with relevant others, can make the decisions necessary to meet the learner's own learning needs". Based on this definition, students are not normally really being encouraged to become independent learners, they are merely learning to respond to the requirements of the lecturer or the assessment. Even though they might get high marks for the work that they hand in, they are not developing a deep understanding of how to approach and, above all, how to define problems. Historically, especially in the first years, most university courses take a similar approach.

Particularly on science and engineering courses, there is a large body of technical and mathematical skills that has to be assimilated. There is really no alternative for students to get to grips with this, other than by using the traditional methods of reading, understanding and practicing, which admits tensions. Of course, helping the students to learn these fundamentals can be done in numerous ways, but in all of these, the students are being taught to provide the “correct answers” or, at least, to use approved methods. This approach tends to spill into other subjects, where the students are busy looking for the correct answer, They are

not aware that, when they leave university and start work, they will be doing jobs where they will be expected to provide solutions that fulfil the requirements, not to provide the (unique) answer to the problem in order to get high marks in an assessment.

The students who are attracted to this type of engineering course tend to be those who have mathematical and scientific skills and interests. They tend to be analytical in their approach and often arrive with the belief that mathematics and technology can provide a solution that will solve all technical challenges. One approach to overcoming this mindset is to use Experiential Learning or Problem Based Learning (PBL).

Kolb (1993) explained the need for experiential learning. He suggested that within this form of learning the student moves from actor to observer and from specific involvement to general analytic detachment. In other words, experiential learning goes hand in hand with reflective learning. Kolb went on to define experiential learning as a continuous process grounded in experience, where learning is developed through adaptation and solving problem activity. Hence, this type of learning is a process of knowledge creation rather than an activity of memorizing information. Experiential learning, according to Kolb, is “the process whereby knowledge is created by transformation of experience”.

However, experiential learning is meaningless without a process of reflection. Barnett (1990) suggests that students should be reflective practitioners, where sufficient self reflection and critical self-evaluation enable students to develop valid knowledge that goes beyond excitement and vain interest in the subject.

Consequently, this type of learning could prevent the students from having a profound understanding of the fundamentals of the subject, which need practise and repetition to get to grips with. In order to fulfil both of these requirements, a more integrated approach is needed.

Mendus (1992) argued that students should be presented with different and competing traditions in order to facilitate critical creation as well as critical discovery. Here at the University of Sheffield Mechanical Engineering Department, in parallel with the more traditional type modules described above, non-traditional modules have been developed. These use the technical skills that are being introduced in other modules (using more traditional teaching methods), but challenge the students to approach a series of far less well defined problems where the process of arriving at a plausible solution is, at this stage, more important than obtaining an exact result.

Two first semester courses, *Enterprise and Technology* and *Mechanical Engineering Techniques*, have been run for the past three years to attempt to close the gap between students' preconceptions of what science and engineering are (either 'soft', design subjects which rely on aesthetics, or mathematically based topics where there is a 'correct' answer) and the reality, which is somewhere in the middle (numbers informing, but rarely being, the outcome).

Enterprise and Technology

The Enterprise and Technology course requires the students to use their existing non-technical and developing technical skills to approach an open ended engineering problem in an innovative way. They can approach it in any way that suits them. The final 'product' is both the technical solution and the non-technical presentation.

The course encompasses a different approach to learning. The objective here is for enterprise skills to become an empowering and powerful set of personal attributes and competencies for each student. Ashworth (1982), who at that time was Vice Chancellor of the University of Salford, a strongly technological institution, made a convincing case for “educating for capability” including: creativity, defined as a capacity to cope and deliver and, importantly, “communion”, encompassing collaboration, human fellowship and mutual dependence, in addition to scholarship and an understanding of subject specific knowledge. As a number of other authors have noted, an important role of enterprise education is to seek to produce educated graduates with specialised knowledge, who are capable of making an impact in society as workers, leaders and innovators, and not to focus too strongly on simply producing specialists (Arora and Faraone, 2003; Keogh and Galloway, 2004).

These skills are taught using Problem Based Learning (PBL) techniques. The general type of assignment is to design a product to solve a day-to-day problem. The assignment might, for example, take the form of a hands-on assessment of flawed products that will lead the students to find novel, alternative answers. A study undertaken by Lucas et al (2006) explores the psychological mechanisms which support the recognition of science and technology-based opportunities for new ventures, and concludes that technology but not venturing self-efficacy predicts higher levels of technology-based opportunity recognition.

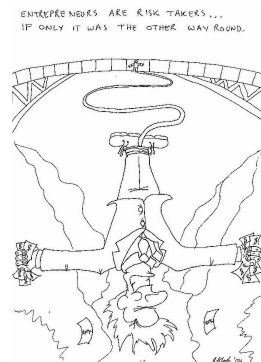
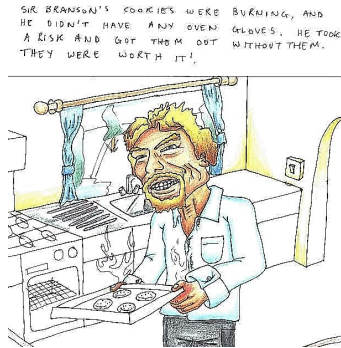
This part of the module’s assessment encourages students to develop their entrepreneurial alertness, a perspective that calls attention to the unconscious processes of discovery, as suggested by Kirzner (1979), through the development of technological self-efficacy.



The practical project tends to work well. Students observe their day to day environment and recognise engineering opportunities. However, the lack of reflection raised by Barnett (1990) still remains and, in order to address this issue, there is a second part to the project. Students are required to select a specific topic of the module or specific learning and produce a reflective piece of work that covers their understanding of the exercise and its ramifications in a creative way. Both the flexibility and the intentional lack of guidance are very alien to the students. However with some suitable prompting most are able to bring skills, either existing or acquired, to this part of the project.

Beck & Rodríguez-Falcón - Student learning on non-traditional modules on traditional courses

Submissions have included poems, songs, cartoons, fictional stories, personal diaries, models, paintings, sculptures and music. Together with the creative piece, students have to submit 300 words answering questions such as: why did you decide on this particular style? what did you learn? Some of the more tractable ones are shown throughout this article.



One of the features of this course that makes it unusual, and also both fun and perplexing for the students, is that the assessment is not of a predetermined form, such as a poster, a report or an exam. The student can produce any form of output that they feel best allows them to get over the message that they have developed. The students are told:

The submission can take the form of a poem, a drawing, a sculpture, a collage, a mix of all. Use any ideas, any resources and any materials and have fun with it.

Students find this task very challenging, as their expectations of an engineering degree are very different. However, the results every year are very encouraging. Students have found year by year new forms of presenting their thoughts. The first year submissions included cartoons, poems and creative

writing. The following year new ideas were implemented, such as songs, paintings and collages. In the last year, video recordings, 3D models, multi-language submissions and others were added to the ever growing list of ways to reflect. On the academic side, results are also better year by year, supporting the argument that students learn from their seniors and improve.

The entrepreneur is born not bred

When I was ten, I didn't have much money
And I spend what I had on sherbet and a lolly
But now I've grown into a more ambitious individual
I would buy the sweets then sell them for double
With proofs like this, I'll refute the lie being spread,
That an entrepreneur is born not bred.

I allowed the opportunity to parachute pass by
When at the age of 16, I was too scared to fly
But now I take risks, I've learnt chances might only
 come once
So I now sky-dive, water glide, and I even DANCE!
All those are messed in the head
That say entrepreneurs are born not bred

Even though I'd passed my driving test, my dad still
Wouldn't let me go anywhere near his car until
I'd learnt the art of negotiating
So I'd wash his car, in return for driving!
How could they ever have said,
That an entrepreneur is born not bred?!?!
And finally, I've always been a quiet sort of person
Not much colour, not creative, not one to start a
 revolution
But having felt strongly about this issue, looked at
 my creation

The minds of people shall be convinced, and history
will be written
So from this day forth, it should never again be
said...
That an entrepreneur is born not bred

The unlimited scope for addressing this exercise means that students are able to bring the optimum learning and presentation styles to the module. Since no single method is prescribed, there is no need to cater for a variety of learning styles; this is implicit in the pedagogy.

This reflections by a second year Civil Engineering student who undertook the *Enterprise and Technology* module highlights another feature of the course, that of creative teaching helping disabled students:

I have taken great joy in trying to convey my thoughts in the way of pictures, as being dyslexic I have great difficulty expressing myself with words. I feel I hit a barrier where words are no longer any use to me. Thanks for this opportunity!

Naturally, there are challenges on this type of course which are different from those on more conventional lecture courses. Most students find this way of teaching unfamiliar and thus uncomfortable. Unsurprisingly, students (like the rest of us) are more confident working within clearly defined boundaries. The scientific background of most of the students has led them to believe that the problems that they are set have a unique, best solution. This is at odds with many real-life exercises, which involve producing an original solution to an open ended problem. Allowing the students to learn this is part of the aim of this module.

Many are initially somewhat confused, as they came to do an “engineering degree not an art degree”. However, with encouragement and support, most are able to produce high quality, reflective work using a medium that they feel will maximise their impact. It is fair to say that most students at the end of the task seem really pleased with their outputs. Most students find at the beginning the idea of trying to be reflective in a creative way unsettling and even annoying but, by the end, according to the narratives provided together with the creative piece, just 3 or 4 out of 70 continue really to hate the exercise. Interestingly, even one year on most students remember what they did and what the learning was, including those who did not like the task. One student, interviewed after 3 years of having completed the exercise, said:

I remember distinctively having done a portfolio of cartoons reflecting on competition, marketing and general enterprise learning; I was very proud of what I did!

Although there are “hundreds of ways” of conducting this part of the project, this clearly is not a problem for students. What has been identified as difficult to handle has been, in fact, the actual assessment of the creative pieces: “marking is specifically a problem” (Hextall, 1976). The marking criteria have to be carefully constructed to address the main learning outcomes of what is clearly not an art project, but a reflective one.

Reflective practice or critical reflection, as presented by Hunt (1999) and Wideen (1987) respectively, provides the basis to reflect upon one’s own practice in respect of learning achievements and understanding. The marking criteria used by this module (Table 1) were developed based on the model given by Hunt (1999) who describes “structured

writing about practice incident”, which gives a three step process: (1) describe what happened; (2) make judgments; and (3) analyse.

	Criteria	Mark/Y
1a	300 words of introduction that answer the following questions: Introduction answers the question why did you decide on that particular piece? What did you learn when you produced it and how?	/X1
1b	The piece shows ability to reflect upon how beneficial the learning can or will be preparedness to make use of the learning understanding about how the learning can impact upon his/her professional career	
2	Reflection presented in a creative format. <i>Creative</i> : an individual way of expression i.e. poems, drawings, diary, music, reflection, etc	/X2
	TOTAL=X1+X2=Y	
FEEDBACK		

Table 1. *Enterprise and Technology* marking criteria

This model encourages the student to be objective, to ask questions such as: what did I learn? how did I learn it? what difference has it made or can it make? It also helps capture and make sense of what was good and bad about the experience:

For this course work I chose to talk about "Dedication" as I feel that it is an important criterion for any entrepreneur and it is one of my weakest links in life. Finally I feel real proud on doing this piece of genius and am more confident on facing challenges that I would run away from in the past.

Dedication in my opinion is going to be my strongest link in life.

I then thought of the different skills that an entrepreneur needs. Amongst my list were: thinking big, being creative, transforming ideas into business opportunities, negotiating skills and a host of other skills. I then thought of a different scenario in which my point could be made, for each of the above mentioned qualities of an entrepreneur. I then reached my biggest obstacle, which was to write the poem itself. It was hard. But, although I'm hesitant to say it, I can truthfully say, I actually *enjoyed* writing the poem.

Alas, I still don't quite believe that *engineers* should be made to write poems. Rather, I think, it's a task that everyone should be made to do.

Qualitative analysis of the reflections

An analysis of 20 random reflections was conducted with the aim of determining the main learning points achieved and the impact (a sample of 10 is shown in Table 2)

The methodology followed was:

1. To read the written account and identify three main aspects:
 - a. Learning identified by the student
 - b. Whether the student identified future use of the learning
 - c. Whether the student thought the piece could be improved or not
2. To analyze trends amongst individuals

Beck & Rodríguez-Falcón - Student learning on non-traditional modules on traditional courses

	What did you learn	What's the impact	What would I change
1	To trust my ideas more To take more risks To work as part of a team	These skills are very important. I will be a better engineer.	I would start my creative piece earlier.
2	Thinking outside the box About entrepreneurship	I am sure all these will be very useful later in my career	Nothing. I am grateful to have been given to learn what I have in this module
3	That one can explore their creativity and therefore increase their capability	It has improved my way of thinking	I would use more techniques to better reflect on what I have learnt
4	That, ideas for a good product may not come straight away, only after careful planning and hard work things turn out better.	As before	I struggle to come up with a good enough creative piece but I succeeded. I wouldn't change anything.
5	That if there is an area in which I am lacking the best way to tackle the problem is to practice and participate.	This will be of vast importance on my professional career as I will be able to improve my performance in areas I am not so confident in.	Nothing
6	That one must think, research, plan and understand about the project before one can even start.	A before	Nothing

7	That many students don't believe business skills are essential when looking for employment: wrong!	I will never forget what I learnt in this class as my creative piece will always be available.	
8	That if I want to achieve something I must persevere, research vast arrays of data to find opportunities and put great amounts of effort.	I will use this knowledge to further the methods of how I work as a student, professional and as a person.	I would learn more about business types to illustrate better my learning.
9	That discovering a market niche is vital to designing a product that will last the test of time.	I will solve problems thinking of this idea.	Nothing. I produced my piece in acrylic paint so it stands the test of time.
10	That which I have learned; Engineers must retain, their Creativity.	This haiku surmises what I believe to be the end result for me.	

Table 2. Analysis of written accounts

Findings

Students, in their accounts, talk about their learning and its impact in terms of capability, trust, exploration, perseverance, achievement and so on. The learning outcomes set initially for the module include outcomes to develop and enhance enterprise skills in students through project work, team work and creativity-related activities. Students do mention business skills, project management, risk assessment and market research in their accounts, however: it is evident that what they identify as their main

learning is much more subjective, as has been previously mentioned. Yet, when they talk about the learning impact, they refer to long lasting learning that will impact on future employment and their personal lives. This latter is not a learning outcome that engineers explicitly set out to meet in degree courses. It is an unintended outcome, but one that the authors believe should be made explicit.

Finally, students do not seem to be very consistent in their intentions to improve their creative pieces “if they had a second chance”. Some believe they would use other ways of expressing themselves in order to “illustrate better their learning”, but mostly they simply feel “proud” of their achievements.

Mechanical Engineering Techniques

Another first semester course, *Mechanical Engineering Techniques*, requires the students to apply softer skills to ostensibly technical problems. The main aims here are: to prevent the students from compartmentalising the topics that they are taught; and to show them that the skills required to be engineers are not just technical. All of the exercises are designed to help the students get to grips with a wide range of skills that graduate engineers are required to bring to their jobs. Reading and understanding technical information, clear writing techniques, and dealing with real data are the things that many practising engineers actually spend most of their time doing. The four exercises set in this course are:

1. Composing instructions on how to perform a simple task, such as sending a text message
2. The statistical analysis of an experiment that was previously conducted as part of the technical program of the course

published, students can find the original abstract.¹ The description of the exercise handed out to the students is:

Your task is to write an abstract for me. This is to be between 150 and 200 words. I also require a very short (maximum 20 word) description of the main points of the paper. Those of you of a more poetic bent may want to put this into Haiku form.

Each of the students submit their work as assignments using the standard university electronic teaching environment (currently WebCT Vista). They can either attach a word processed document or paste their work directly into the submission box on the assignment section. No marks are given for presentation, though there is a penalty for poor language. In the case of very poor work, or where the student has missed the point entirely, the work is returned (electronically) and the student encouraged to resubmit a better piece of work.

For the first two years, the exercise was only made available online to the students, along with some notes describing the exercise and the requirements, and the resulting submissions marked with feedback provided. This gave somewhat random results as many of the students did not seem to read the notes very carefully or engage with the exercise on a more than superficial level. From the third year, however, the Sheffield University English Languages Teaching Centre was contacted and a lecturer was provided who gave an entertaining lecture on writing abstracts – and Haikus.

One paper students are asked to summarise is about the comparison between experimental work and a computer

¹ Incidentally, teaching this exercise has improved the quality of the authors' own abstract writing.

model (CFD) of a novel way of examining fluid flow (Tomlinson et al, 2006). The interesting part of the paper is that a standard fluid modelling package was used, in contrast to previous published work which relied on bespoke computer modelling techniques. Below are some example of effective student summaries. Here the students are able to extract the main elements of the work and to critically put it into the context of previous research. The first two are a pair of 20 word hyper abstracts:

Two types of flow were investigated and CFD codes used to produce a simpler method for modelling birefringence flows.

To avoid complex code-writing, this investigation aims to establish whether simpler modelling methods using commercial CFD code create accurate analysis of birefringent flow.

The next two are paragraphs extracted from the main submission:

Through comparison of the computer models and the three and two dimensional experimental analysis in expanding jet and cavity tests respectively, agreement was noted between the two sets of results. The agreement was good as the models showed similar patterns in the fringes as the experiments, particularly in the cavity test.

This preliminary study could be furthered by implementing other variables, such as non-Newtonian flow and shear rate calculations, into the investigation. However, the method shows promise as the initial aims of finding a simpler way of

modelling birefringent flows accurately has been achieved in both geometries tested.

Here is an example of someone who has not read the paper very well. This student is writing about the background to the problem, not what the paper was about:

CFD software is a simple way of modelling the birefringent effect. Birefringent effect is caused by the deformation of molecules in transparent materials.

Most of the submissions fall somewhere between these two. These submissions usually suffer from either structural errors, such as not using three paragraphs (the problem, what was done and what it means) to marshal their thoughts, or leaving out complete though vital parts of the work, such as the experiment.

Below are some of the best Haikus from a previous year, and thus a different paper. It is easy to see that these students enjoyed the exercise and have really tried to extract the most important points from the paper. I particularly like the use of the pentasyllabic “emissivity”.

A radiator
With a dull wall behind it,
Will transfer more heat.
Radiated heat
Heats up wall, wall heats air too
Ideal? Maybe

Dull walls heat up,
Warming air. Shiny walls stay cold.
Insulate your walls.

Emissivity!
Painted black, shiny surface
Low cost means heat loss.

Conclusions

Student feedback is extremely variable for these modules as many students fail to appreciate that engineers require skills in communication, negotiation, social and environmental awareness and reflection in addition to their engineering science training.

Independent learning tends to be a ‘not-assessed’, difficult-to-measure outcome of University degrees. Students tend not to value that which is not assessed and therefore do not treat it as a valuable part of their learning experience. However, the development of values, attitudes, knowledge and skills is indeed needed to make professional and responsible decisions. The best outcome students can achieve is to take independent action and thus deal with their own learning. We, as learning facilitators, must foster this activity by creating the opportunities and experiences that encourage student curiosity, self-confidence and motivation.

Another key element of learning is the time students spend reflecting on what they have experienced in the classroom. Barnett (1990) is adamant in saying that reflection is critical to effective learning. Causing rapport in students can last only so long.

Students who have done these exercises tend to remember them and take away a different skill base from that which they were expecting. These skills are as important as the traditional skills that engineers learn. There is little point in having superb analytical skills if you cannot put them into context, use them in novel ways or communicate them to others.

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Beck & Rodríguez-Falcón - Student learning on non-traditional modules on traditional courses

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