

## Motivation of engineering students – considerations for programme design

Sarah Green<sup>1</sup> (s.green@lancaster.ac.uk), Erik Meyer<sup>2</sup> (j.r.f.meyer@durham.ac.uk)

<sup>1</sup>Lancaster University and <sup>2</sup>Durham University, United Kingdom

**Abstract:** *The learning approaches adopted by three finalist engineering undergraduate students following an integrated MEng programme in engineering at the University of Durham are examined. Using a common questionnaire and one-to-one interviews, inter and intra variation in student learning and the student perception of the learning environment was explored. The students studied shared similarities and exhibited differences in their approaches to learning, which were found to be context dependent. Evidence of inter and intra variability in student learning, the extent of students' engagement with surface and deep learning approaches, and the correlation of these outputs with the level of the programme is discussed. From this study, a number of specific points for professional practice are discussed.*

### Introduction

Many studies of higher education students have found variation amongst those students in both the way that they learn and the subsequent outcomes of that learning experience. The causes for this variation in the quality of student learning are multivariate, being influenced by factors beyond the inherent academic ability and aptitude (capacity) of the individual student (Meyer 2007).

A number of studies have shown that the level of engagement with both subject content and subject context, ie at module/course/activity level, of an individual student is also subject to variation (ie intra-individual and inter-individual variation in student learning exists). In process terms, ie what the students actually do when undertaking a learning task, the concepts of 'surface' 'deep' and 'strategic' approaches to learning are informative (Biggs 2003, Entwistle 1997). In parallel, the student's organisation of information "the study orchestration" (Meyer 1991), whether they construct an atomistic/disparate or holistic structural framework for the information learned, will also influence the ultimate learning outcome. Marton and Säljö (1997) conclude that the deep/holistic approach is the only way to achieve academic understanding. The learning approach adopted by a student is further mediated by the student's interaction with and perception of the learning environment. This increases the likelihood of discipline specific variations in student learning given that contextual environments can vary considerably between subjects. Extending the work of Marton et al (Marton 1993) but concentrated in the engineering field, Marshall undertook a study to characterise the qualitative differences and similarities in the conceptions of learning held by engineering students, yielding discrete categorisations into (Marshall, 1999):

1. Learning to increase one's knowledge
2. Learning as memorising definitions, equations and procedures
3. Learning as applying equations and procedures
4. Learning as making sense of physical concepts and procedures
5. Learning as seeing phenomena in the world in a new way
6. Learning delivering change as a person

Encouraging learning at levels 4 and above, ie using deep approaches, should be the aim of meaningful higher education. Within science and engineering, an externally regulated and content heavy curricula is commonplace, with students experiencing typically double the timetabled contact hours of students reading non-scientific subjects. The educational research suggests that this may be counterproductive to encouraging deep learning approaches. Gibbs (Gibbs 1992) identified course

indicators that were conducive to encouraging a surface approach in students, these being: a heavy workload; relatively high class contact hours; an excessive amount of course material; a lack of opportunity to pursue subjects in depth; a lack of choice over subjects and a lack of choice over the method of study and a threatening and anxiety provoking assessment system.

Entwistle and Tait (1990) found that the perception of a high workload was correlated with a tendency towards surface learning and reproducing strategies in two studies of first year engineering undergraduate students, work which was corroborated by Kember et al (1996,1998). In recognising the importance of encouraging deep learning approaches, the Engineering Professors Conference recommended that efforts should be directed toward keeping the content of undergraduate engineering courses to manageable levels (Sparkes 1989). In 2002 Rowe reviewed the approaches to studying adopted by 113 first year electrical and mechanical engineering undergraduates at Sheffield Hallam University. Although a negative correlation was found between the end of year results and a tendency toward surface learning approaches, no positive correlation could be found between approaches categorised as meaning orientated and the students' final year grade. Further, no negative correlation was found between a reproducing orientation and the students' final grade.

## Background and Methodology

This work examines the learning approaches adopted by a small sample of students following the Durham University master of engineering (MEng) programme, a Level 7 qualification in the UK framework for higher education qualifications (FHEQ). In the UK, undergraduate engineering education via an integrated MEng is the normal route to meeting the educational requirement of Chartered Engineer professional member status (CEng) with engineering institutions affiliated to the UK Engineering Council (EC<sup>UK</sup>). The academic profile of students entering the Durham MEng is above the UK engineering undergraduate programme average, requiring AAB A level grades and reflects the academic challenge of the programme, the market value of the graduate output and the attraction of the University. The four year full-time Durham MEng has ca 20 timetabled contact hours in addition to which, 20 hours per week of student self-study is recommended, which is also above the UK average for engineering programmes. Unlike specialised/named engineering undergraduate programmes, at Durham students follow a common general engineering curriculum during years one and two (ie Level 4 and Level 5 FHEQ) prior to part-specialisation in year 3 (Level 6 FHEQ) into mechanical, electrical, civil or electronic streams. The rationale for this approach is to ensure a comprehensive underpinning of key engineering concepts and knowledge as preparation for specialisation in later levels of study. Upon progressing into the Durham MEng final year (Level 7 FHEQ) they follow one of eight named streams, undertake a stream-related final year research project of their choice (weighted 50% of their final year mark) and the lecture load decreases to 50% that of earlier years. The work presented here examines the learning approaches adopted by three final year engineering undergraduate students following the Durham MEng programme and undertaking final year research projects supervised by one of the authors (SG). The three students were self-selected following an open invite to participate in the study. Two of the students were following the MEng Mechanical Engineering stream and one was following the MEng Civil Engineering stream and their individual academic profiles spanned three inter-quartile ranges of the 126 student cohort mark sets (Table 1). The study utilised a common questionnaire and an interview session held mid-way through the final year and the final year project. Students were asked a series of open questions designed to explore their perceptions of the MEng course in terms of workload and difficulty and the consequential strategies/methodologies adopted by the students during study. With regard to the final year project, via the questionnaire and interviews, emphasis was placed upon exploring the learning approaches adopted by the students in undertaking the literature review and their management and delivery of the project. All interview sessions were recorded and the student responses were transcribed for review and analysis. Via this approach, the inter and intra variation in student learning and the student perception of the MEng learning environment for these students was explored and is discussed.

Interviewee	MEng Stream Followed	Research Project	Academic profile <sup>1</sup>
Student A	MEng Mechanical Engineering	Bioengineering	29/126
Student B	MEng Mechanical Engineering	Bioengineering	70/126
Student C	MEng Civil Engineering	Civil engineering materials	110/126

Table 1 Engineering students interviewed

<sup>1</sup>Final placing in 126 student cohort

## Results

### Student A – Following MEng Mechanical Engineering

Student A's perception of the MEng course and associated examinations was one of memorising and accumulation of knowledge and he adopted learning approaches to satisfy these requirements.

*“you can go through engineering quite well without having to understand anything, just learning examples and applying it in exams. Some things I haven't understood in the course and I've just literally just memorised....I think that anyone could do this [course], if they worked really hard. I see the engineering course as information gathering and downloading to pass the exams”.*

The student is aware that such an approach is counterproductive and unfulfilling but has been sustained by high motivation and a desire to succeed.

*And that [approach] has been rewarding? “No....it's just the way it's taught, I've found it insanely boring, just not very stimulating....I've had one inspirational lecture and that's it, a first year lecture on fingers - so I knew I wanted to do that sort of project in bioengineering and also I had medical project and a lecture course last year”.*

These responses indicate that learning processes have been accumulative/surface for much of the course to date for this student, although this is not the case for the final year project. However, despite adopting what could be viewed as a surface approach to learning, ie memorising/factual recall, the student did not feel excessively time pressured through the course. As the course has progressed and in particular as the student has been undertaking final year research work, the perception of the workload has shifted.

*“Sometimes [I've felt time pressured] towards deadlines, but not always. I've found it ok – as long as you worked steadily and didn't leave it all until the end. I've been enjoying more what I've been doing [this year] so it hasn't been such a chore having to do it. I have spent about the same time overall this year on studies compared to previous years”.*

Course content that is theory based has been less popular with this student, but perception of theoretical background and its relevance to the course as a whole has shifted as the course has progressed, indicating a transition from quantitative to qualitative learning processes on the part of the student. In Marshall's categorisation, with course progression, the student has moved beyond level 3.

*“Sometimes we just go through pages and pages of derivations to get to the final thing and then you just have to use the final equation or something and I think, oh, why couldn't we just go straight to the equation ... but I'm getting better at understanding why we derive things – I'm seeing more of the point of it. As I come closer to the end, I'm seeing better links”.*

When asked what the project offered, the student regarded the final year project as an opportunity for self-development, indicating student engagement beyond that of a solely result/outcome orientation:

*“To learn how to work on your own, to develop research skills. You're nurtured quite a lot of the way along...so you're released, so you can establish a bit of your own working pattern, to be self dedicated...I took control of [the project] – had ownership”.*

The student's intention to understand and sense of ownership of the project are evident here, factors which encourage deep learning (Ramsden 2003)

The student's responses to questioning on the processes involved in the construction of the project report and of the writing of the literature review demonstrate that he was using deep learning processes. For example, for the task of literature review, he describes being actively engaged in constructing meaning:

*“Because I had no idea really of what I was getting in to, when I started the literature review it was magically finding out what things meant. At the start I'd read things but didn't understand them. They were just words, so I kept rereading, going to easier papers/books and gradually the words became something, had meaning”.*

In constructing meaning, the learning task is for this student in this context, transformational. It is altering his view and understanding of the subject. On describing how that personal meaning was constructed:

*“When I read through things I needed to get an outline/overview for myself. When you read something difficult, conceptually, it is just words so I then go about finding the meaning of those words and phrases. I continue this process so that I understand the paper, reading the same thing quite a few times. And then just going out and finding information from other sources, simpler books, other papers”.*

### **Student B – Following MEng Mechanical Engineering**

This student's responses to the questionnaire suggest that he has a high awareness of time pressure and regards the engineering course to be content heavy, echoing the common complaint in science and engineering curricula (Kember 1996). Notably though, this emphasis/perception has changed as the course has progressed, and particularly so during the final year.

*“The first and second years I found it hard in terms of just number of hours, particularly in second year. The sheer amount of contact time, it left me no time left to do anything else in the week. This year's much better...so I have had time to do the work that I've needed to do...and have a life as well. It's not got easier in terms of content but in terms of having the time to be able to do what I needed to do for the course”.*

This shift in time sensitivity by the student, in particular by exploring what it could be attributed to, was followed up in the interview *“Using the odd couple of hours every day which are just spare – trying to break [the course] into far more chunks... My time management has changed, as a result of not being tied into lectures all day every day; I've been able to do that”.*

In considering the time committed to project work this year, the student's response indicates that the learning approach adopted is subject to contextual variation, with inequalities existing in hours committed to the learning tasks of lectures and project work.

*“[Project time spent] is more than lectures but generally with lectures, I just go to the lectures and then learn it all over Easter. Before the exam period, I don't tend to do so much work. Throughout the year, I just go to the lectures, get the notes and learn it all before the exams. Coursework, and in particular this project, is very much more ongoing”.*

The student reveals that motivational factors influence his preferences towards the type of favoured course content and particular subject area. In his case, exposure to a first year module generated the interest which was sustained through the later years of the course and ultimately influenced his choice of final year project.

*“I've always been more on the problem solving side rather than the sitting down and crunching equations... it's why I came into engineering, it's just what's appealed to me from the outset. [Motivation has been sustained] partly as a result of a first year module on biomedical engineering. I was interested in it back then and we didn't do anything on it until fourth year. I just thought it was really interesting back then and I was a bit annoyed that it didn't pop up again in second or third year – I would like to have seen a bit of it during those years. [The lecturer] was very good at lecturing, he kept us interested, but at the same time I just hadn't seen any of it before – it was completely new, it was applying physics and maths and different ideas that we'd all learned for a few years - things that we knew and putting them into a completely new area”.*

This clearly had a strong motivational effect on the student, and this motivation was facilitated by his prior knowledge of the underpinning physics and mathematics. This illustrates the importance of prior knowledge in the 'sense making' process of deep learning, without it, although the lecture series may have been interesting/entertaining, it would have had less personal meaning to the student.

In motivational terms, the student also highlighted the importance of the final year project:

*“... [the project] has reinvigorated things. Towards the end of third year I was really quite fed up with it and a bit annoyed the way things were going, as it wasn't hands on, I wasn't getting involved with anything. The project certainly helped me get back on track in that sense”.*

For the final year project, the student's perception of the project review meetings was that they were somewhat peripheral to the main work of the project, perhaps even being viewed as an external imposition rather than a forum at which to develop ideas and understanding. The perception of external imposition and unreflectiveness are both characteristics associated with surface learning.

*"...[prior to the supervision meeting] I'd think, what do I need to ask tomorrow. For quite a lot of the time, particularly second half of last term and the first half of this term it was just progression from one week to the next and there wasn't really anything different."*

When questioned what the student believed the purpose of the final year project to be, the perception was one of gaining more depth in a particular subject area:

*"Try and learn one thing in depth....until now, everything has just been an overview; to give us some kind of ownership of the project, which I think is going to be applicable in the real world. To really test how well we can get into a whole year project, because if we can't do that now, we're not going to be able to do that in our working life. Kind of test that, as much as the actual content".*

*"I don't think [my understanding] has changed that much. I did quite a bit of reading over the summer. I certainly understand it better now; the proportion of how much I understand has changed. To begin with I thought it was sort of a combination of biology, engineering and materials science and I still think that that's the case, but I just know more about each of those areas".*

This answer indicates that at least in part, the student holds a quantitative, accumulative perception of learning in this task. Little inference can be made toward the development of deep understanding or gaining meaning and the descriptions cannot be interpreted as the student viewing the project as a transformational learning activity. Although the overall significance of the project was viewed in a surface/accumulative manner by the student, when questioned on the detail of the project, ie writing the report and achieving understanding of project-relevant scientific papers and concepts, the student's responses indicate that he was using deep learning processes.

*"[The literature review] changed as it's gone on really, I've had to go back and change things, it's been fairly iterative. I'd just read a whole paper and try and take notes and that wouldn't necessarily make all that much sense until I'd read another paper which would relate back to it, and then I'd understand the second one more, or I'd progressively understand it more, the more I read. I'd initially read each paper and take notes then I'd re-read my notes a good few times when I was trying to make my document. Probably towards the end I'd go back and read the original paper once more".*

This description fits with at least Level 4 of Marshall's categorisation of student learning (Marshall 1999). When questioned on the mechanisms employed when deciding at which level to pitch the literature review, again deep learning, 'sense making' processes on the part of the student could be identified:

*"I tried to write the paper for somebody reading from the outset who doesn't understand the project, so if they read through my paper, by the end of it they'd understand it. So I've tried to write my literature review based upon what I had to do in order to understand – get from where I started to where I am now".*

The student here is describing constructing personal meaning, rearranging and reconstituting information during the learning process, all of which are examples of using deep learning processes.

### **Student C – Following MEng Civil Engineering**

When questioned, the student did not perceive the engineering course to be associated with an unduly heavy workload or to create for him, excessive time pressure:

*"The first two years have been very different from the last two years. A lot of lectures and not a lot of project work whereas this year it has been a lot more independent, but I've quite enjoyed this year. I've actually found it quite relaxed... a bit more time on my hands. I'm quite good at time management. I'm quite focussed. I'll go to the library and get my work done and I'll go and do something else. I think that's one of my really strong points"*

His responses indicate that he has well developed time management skills and is very organised in his approach to work for the engineering course. In this manner, he adopts a strategic approach to learning in this context.

The student's view of project meetings was somewhat superficial, viewing them as not particularly significant to the overall project progression.

*"If stuck on something, it was useful to get help...just to keep on the right tracks really. [Towards the end] I've found more need to come and meet for technical advice/direction. Throughout the week, if I*

*had a q I'd write it in my book. I wouldn't sit like down before the meeting and go right I'm going to ask this and this. If things cropped up throughout the week, I'd just like write them down".*

The student's perception of the purpose of the final year project was quite revealing, concentrating on discrete details rather than the composite whole. This atomistic view of the project is indicative of a surface learning approach:

*"Even though the theory of this project is probably quite important to me, because everyone's doing something different, it's not that important for your degree, I mean you don't need it for exams."*

This response reveals a strategic mindset in this student; he is focussed towards exams and outcomes to a greater extent than learning *per se*. This was followed up in the interview questioning:

*"Usually...I've always hated projects. I'd rather just have an exam, but I've quite enjoyed this project. Usually I hate waffly writing, usually I prefer something just there, to look at it and answer a question on it. But I quite enjoyed doing the research and the reading around it and whereas in an exam maybe it's something that you don't find interesting, like quite a lot of my lecture courses I really do not find interesting...but I want to get a degree".*

Here he demonstrates outcome driven motivation, which is a feature of a strategic approach to learning. However, identification/awareness of the relevance of the subject matter is clearly important to this student in sustaining his interest:

*"[On uninspiring lectures]...I think when am I ever going to use this in my life? What is the point of me learning this, it doesn't challenge me".*

When questioned on how he dealt with difficult concepts in his engineering studies, his responses indicate that learning and understanding for him involves visualisation of the content.

*"Stress analysis, I actually find quite difficult, [x] is an amazing lecturer, such good notes and makes lectures quite interesting. I do find I'll read though the lecture notes, I'll read books, and I'll still find that the questions are just... I can't seem to visualise. I find asking a friend, if they can explain it to me, I usually find that really helpful because they're sort of on your wavelength".*

*"When I first read quite a simple paper I really wasn't sure what was going on...I couldn't really visualise. When I read the discussion, I knew that I didn't understand it because I couldn't memorise what was going on in the paper, but now, after I've done everything, if I read that paper again, I can read it really easily, really quickly, I know what's going on. I see the paper in a completely different way. Before I literally just read it but it wasn't going into my head".*

This last reference to memorising the paper is indicative of a surface, accumulative approach to learning in this context, rather than the construction of personal meaning indicative of a deep approach. When questioned on the processes adopted when writing the literature review and the project report as a whole, some evidence of deeper learning processes are evident, but there is still a quantitative, transferral view of knowledge even during the writing process.

### **Response Themes**

To summarise the responses across the student group, for student A, intra-student variability in learning approaches were highlighted with the variability observed to be context dependent. In earlier years of the course, more strategic, reproductive strategies were adopted by this student; a strategy encouraged by the student's perception of the course assessment requirements. In contrast, for the project, deep learning approaches were evident, fostered by high intrinsic motivation and interest in the project subject area. By taking ownership of the project, deep learning processes of actively seeking meaning and understanding were employed. The project for student A confirms the model of Gibbs (Gibbs 1992) in that the project 'learning environment' offering study in depth in a subject of choice and freedom from excessive lecture load was conducive to deep learning. For Student B, the learning approaches were also context specific, with the final year project found to encourage deep learning processes. This contrasts with student B's descriptions of earlier course years, which were perceived as having a heavy work load and significant time pressure, both of which are indicators for a surface/strategic approach (Gibbs 1992). For Student C, the interview responses highlighted less intra variability in learning approaches for this student. He was more evidently outcome focussed, having exhibited a strategic learning approach to lecture based course content. For the project, fewer holistic and deep learning approaches could be readily identified in comparison to the other students. Indeed many of his responses can be mapped to Levels 2 and 3 of Marshall's categorisation (Marshall 1999), levels which fall below those recognised for deep learning.

## Reflection and Implications of the Student Responses

Notwithstanding the fact that this is a statistically small study, it can be concluded that these engineering students share similarities and exhibit differences in their approaches to learning, which are context dependent. For students A and B equally, early inspirational lecture content in an area of interest, and which was relevant due to prior knowledge, has provided strong motivation and encouraged deep learning approaches to be used in their final year projects. The students demonstrate inter and intra variability in student learning with evidence of surface and deep learning approaches being used by all three, but the balance between them differs for each student. Gibbs' (Gibbs 1999) indicators for surface learning in engineering courses are confirmed by these students, with surface learning strategies identified and attributable to a high volume of course content and a perception of an assessment environment which does not penalise reproductive strategies, findings which echo the conclusions of Rowe (Rowe 2002). However, the student responses indicate that this counterproductive learning environment diminishes in the final year when the students undertake their final year project. The combination of in-depth study in a subject of their choice and for which they have a degree of control over the project time management and direction is an environment which is conducive to deep learning. Inter-student variability in the extent of project engagement and the extent to which deep learning approaches are used exists, reflecting differences in intrinsic motivation, level of subject interest and academic ability. Across this small sample size, a correspondence was found between academic achievement and degree of engagement with/exhibition of deep learning processes, ie learning at Level 4 and above in Marshall's categorisation. From this study, a number of specific points for professional practice can be drawn.

The study has highlighted the importance of motivation to these students, developed by an intrinsic interest in the subject matter. This interest and motivation can be fostered by early exposure to engineering content that is seen as relevant to students, using content which bridges the gap between earlier academic (A level) material and new, unfamiliar higher level engineering concepts and applications. Appropriate material can inspire the students and lay the foundations for deep learning approaches. For first year students, this can be achieved by reference to current A level science syllabi and perhaps incorporation of some lower level bridging content/examples to reinforce the material. For later years, this can be achieved by regular inclusion of applications based content and references that demonstrate the 'real world' relevance of underpinning theory.

In this small study of three undergraduates spanning the academic ability profile of the cohort, it is evident that the engineering final year MEng research project provided a learning environment that encouraged deep learning processes in the students. The MEng research project typically contributes a significant element of the final award (22% at Durham) and this study supports the continued high weighting of this assessment component.

Notwithstanding the small sample size, this study echoes earlier works (Rowe 2002) and has implications for the design of engineering examination questions, which should be set with an emphasis upon measurement of understanding and an appreciation of fundamental concepts and principles. The aim must be to assess deep learning rather than surface, reproductive approaches through an assessment environment that delivers a positive correlation between meaning orientation and examinations performance.

### References

- Biggs, J. B. (2003) *Teaching for Quality Learning at University: What the student does* Open University Press, McGraw-Hill Education, Maidenhead. Ch 2.
- Entwistle, N. *The Experience of Learning, 2<sup>nd</sup> Ed.* Scottish Academic Press, Edinburgh. Ch1
- Entwistle, N and Tait, H (1990) *Approaches to learning, evaluations of teaching and preferences for contrasting academic environments* Higher Education **19** p169-194
- Gibbs, G. (1992) *Improving the quality of student learning through course design*, in Barnett, R. (ed.), *Learning To Effect*, Buckingham, SRHE / OU Press
- Kember, D et al (1996) *An examination of the inter-relationships between workload, study time, learning approaches and academic outcomes* Studies in Higher Education **21** p347-358
- Kember, D and Leung, DYP. (1998) *Influences upon students' perceptions of workload* Educational Psychology **18** p293-307
- Lizzio, A., Wilson, K. and Simons, R. (2002) *University students' perceptions of the learning environment and academic outcomes: implications for theory and practice.* Studies in Higher Education **27** p27-52
- Marshall, D., Summers, M. and Woolnough, B. (1999) *Student's conceptions of learning in an engineering context*, Higher education, 38, pp291-309

- Marton, F, Dall'Alba, G and Beaty, E (1993) *Conceptions of Learning* International Journal of Education Research **19** p277-299
- Marton, F. and Säljö, R. (1997) *The Experience of Learning, 2<sup>nd</sup> Ed.* Scottish Academic Press, Edinburgh. Ch3
- Meyer, J.H.F. (1991) *Study orchestration: the manifestation, interpretation and consequences of contextualised approaches to studying.* Higher Education **22** p297-316
- Meyer, J.H.F. (2007) *Working Paper on Variation in student learning: An empirical nested model* Scholarship of Learning and Teaching – Jan 2007, Course Documents <https://duo.dur.ac.uk>
- Ramsden, P.(2003) *Learning to Teach in Higher Education (2<sup>nd</sup> Ed)* RoutledgeFalmer, London Ch5
- Rowe, JWK (2002) *First year engineering students' approaches to study* International Journal of Electrical Engineering Education 39 p201-209
- Sparkes, J.J. (1989) *Quality in engineering education*, Engineering Professor's Conference Occasional Papers. No 1. UK.

Copyright © 2009 Authors listed on page 1: The authors assign to the EE2010 organisers and educational non-profit institutions a non-exclusive licence to use this document for personal use and in courses of instruction provided that the article is used in full and this copyright statement is reproduced. The authors also grant a non-exclusive licence to the Engineering Subject Centre to publish this document in full on the World Wide Web (prime sites and mirrors) on flash memory drive and in printed form within the EE2010 conference proceedings. Any other usage is prohibited without the express permission of the authors.