

***The Proceedings of the 7th Annual Conference
of the UK & Ireland Engineering Education
Research Network***

***Excellence in Engineering
Education for the 21st
Century: The Role of
Engineering Education
Research***

Jane Andrews: Graeme Knowles: Robin Clark

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Executive Summary

This document includes result is five distinctive themes covering a wide-range of challenges and issues whilst also highlighting excellence in the area of engineering education. The five themes are:

1. Engineering Education in the 21st Century: Twelve papers provide a breadth of insight and discuss within the wider concept of engineering scholarship.
2. From Outreach to Lifelong Learning: Practice, Policy & Paradigms in Engineering Education: Our largest theme includes thirteen papers each one covering a different aspect of the wider 'engineering education' portfolio.
3. Technology Enhanced Learning in Engineering Education: The third theme is something of a misnomer as the use of technology to enhance learning runs through the conference. However, seven papers looking specifically at the evidence, issues and challenges of TEL provide much food for thought.
4. Teaching Transferable Skills: Covering everything from the teaching of maths and stats to pedagogic practice in study skills and research methods, six papers provide a wide-insight into current practice and engineering education research in this area.
5. Invited Panel: What can we learn from other disciplines? Including a synopsis paper, six different educational scenarios are given in this section which is provided by colleagues from a business and management background who teach non-engineering subjects to engineers.

The theoretical and conceptual underpinnings of seven highly interactive workshops form the final section of this publication

Foreword

*The 7TH Annual Conference of the UK and Ireland Engineering Education Research Network promises to be the largest and most exciting event we've held thus far. The conference has slightly changed direction this year in that we have purposefully selected to focus both on engineering education research **and** practice. Continuing discussions around how we attract, engage, enthuse and education future engineers, the conference comes at a time of unprecedented uncertainty in the UK. With expectations and standards necessarily set high, the need for engineering education to provide young engineers with a broad range of engineering related technical skills and competencies together with a wide variety of transferable softer skills is increasingly important. At a time when students' a priori knowledge and education are seemingly juxtaposed against the prerequisite requirements of engineering education, the need to look critically at the scholarship of how and what we teach within and across the engineering curriculum is vital. Moreover, with numerous extraneous stakeholders, including professional bodies and employers, vying for a say in not only what is taught but also in how young engineers are educated, those responsible for educating the next generation find themselves having to balance a range of different needs, pressures and requirements.*

Within this complex picture the final outcome of engineering education is to produce highly skilled young people capable of solving society's problems and able to make a unique contribution in imagining, designing, innovating and maintaining a sustainable and cost-effective future. Connecting dreams and reality, the past and the future, science and society, engineering has an essential role to play in every aspect of human life. This conference brings together colleagues from Ireland, Europe, the UK and elsewhere, to discuss and reflect upon the challenges and strengths of engineering education through the application of sound research methodologies and scholarship.

Jane Andrews: Graeme Knowles: Robin Clark (Editors, EERN, December 2019)

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Theme I: Engineering Education in the 21st Century

Just as the Fourth Industrial Revolution is radically changing the way organizations deliver sustainable value to markets and the world, a global revolution is also underway in how we educate, develop and grow engineers who can contribute and prosper in this brave new world. A highly connected, rapidly changing, global industrial world with increasingly complex socio-technical problems requires engineers who are not just technologically savvy and professionally competent in their discipline but, increasingly, ones who are culturally aware, interdisciplinary in outlook and possess the personal attributes to be effective as their context evolves. In education this means an increase in pedagogies grounded in real-world contexts, and an evolving conversation with businesses and professional bodies around balancing discipline-based knowledge and the acquisition of broader interdisciplinary competencies and transferrable skills.

The more explicit inclusion of external stakeholders, as in Degree Apprenticeship provision, has led to a deep consideration of where and how learning happens, as well as how we should best constitute the nexus of theory and practice – and how we manage these emergent relationships to provide engineers with an optimum opportunity to grow and develop. Technology looms larger than ever in the educational discourse in the 21st century; offering seemingly limitless possibilities for increasingly personalised learning and ever-expanding toolkits to foster engagement and enhance the learning experience. Again, though, this is not a simple equation; we need to carefully draw the boundaries between appropriate pedagogies and technological innovation. So, in summary, Engineering Education in the 21st Century offers enormous potential to reinvigorate and reinvent, but come with the challenge of rebalancing our understanding and challenging accepted norms. Our role, however, is still to create environments in which engineers can grow into their potential, and deliver radical and sustainable change to society.

Meet the new boss; Same as the old boss!

Graeme Knowles, Head of Education Innovation Group, University of Warwick Organising Committee

Life on Chalk Front: Learning & Teaching in Engineering Education – A Reflection on Colleagues’ Observations

Andrews, Jane Clark, Robin Knowles, Graeme
WMG, University of Warwick

jane.andrews@warwick.ac.uk

KEYWORDS: Change in Engineering Education: Qualitative Interviews: Colleagues’ Perceptions

ABSTRACT

This paper provides a short overview of one of thematic phenomena identified in a qualitative study in which forty-eight colleagues were interviewed about how engineering education is provided, managed and taught in a large Engineering Education Department within a Russell Group University. Aimed at provided an empirical grounding for change, and termed the ‘Herding Cats’ Project, an Action Research philosophy was adopted to provide an insight into colleagues’ first hand experiences and insights of teaching.

INTRODUCTION

Grounded in the findings of a series of qualitative interviews conducted between February and May 2019, this paper reflects upon colleagues’ perceptions of working a multidisciplinary faculty in which engineering education forms an important component. Beginning by briefly setting the context, a short overview of the methodology is given before verbatim quotations are used to illustrate colleagues’ experiences.

CONTEXT

Set in WMG, an academic department within the University of Warwick, the interviews took place at time of uncertainty following the untimely death of Lord Bhattacharyya. Established in the 1980's, WMG has an international reputation for its cutting edge engineering and technical research (WMG, 2019). Comprising seven research and education centres on the Warwick Campus; WMG delivers world leading management and engineering education to just over 1,500 students (including 1,200 graduate students). Additionally the department works closely with industry to provide a range of Higher Apprenticeships in Engineering, Manufacturing and Health Technology (WMG, 2019)

An unprecedented rise in student numbers has seen enrolments on graduate level programmes in WMG increase from around 400 some five years ago to just under 1,300 this academic year. Such rapid growth has not been without challenges in terms of the practicalities of accommodating teaching and employing sufficient numbers of staff to assure students receive a high quality education.

THE DRIVE FOR RESEARCH GROUNDED ORGANISATIONAL CHANGE

With the underlying aim of affecting a paradigm shift in which engineering educators are recognised as holding equal professional standing to researchers, the majority of teaching staff within WMG **do not** reflect stereotypical notions of 'traditional' engineering academics who are generally perceived to be white, middle class, middle aged males with little or no real life or work experience (Carter-Black, 2008). Indeed, the department is unique in that the majority of its educators possess many years industrial experience and bring with them a depth of insight and the ability to use real-life case-studies based upon their own practice.

Within the department, one of the externalities of the recent rapid growth in student numbers has been an increase in the amount of organisational pressure colleagues are facing as workloads expand to reflect student numbers. With pay generally lower in academia than in the engineering and management professions, the value that qualified and experienced teachers bring to higher education should not be underestimated. Likewise, at a time of political

uncertainty, with the omnipresent uncertainties of the Brexit debacle impacting the whole economy including higher education, the need for strategically and professionally planned and delivered organisational change has possibly never been so important (Jick, 1993; Kotter, 1996, 2008). Encapsulating the first of 10 key steps to successful organisational change articulated by Jick (1993) the interviews aimed to provide first-hand accounts of “Life on the chalk front” in terms of what was, and was not, working in learning and teaching

METHODOLOGY

Adopting purposive sampling techniques (Bryman, 2013), over 60 colleagues were invited to participate in a qualitative interview. Forty-eight responded positively and utilising an Action Research philosophy (Norton, 2009) were interviewed about their experiences and insights of learning and teaching practice and policy within WMG. A phenomenological approach was adopted whereby semi-structured interview techniques were used so as to encourage colleagues to reflect upon their experiences and perceptions, giving firsthand accounts of their lived experiences (Stewart & Mickunas, 1974; Sokolowski, 2000).

- The Interviews

The semi-structured interviews centred around three fundamental interview questions which acted as a catalyst for conversation:

1. **What** *part of your own and others’ teaching practice do you feel to be of high quality?*
2. **Which** *aspects of teaching and learning could be improved?*
3. **What** *practical and pedagogical innovations could be put into place to help you improve your own teaching?*

SUMMARY OF FINDINGS

This paper focuses on one emergent theme to be identified during the data analysis: *positive practice in learning and teaching*.

- **Colleagues' Skills and Experience**

Colleagues' perceptions of their own and others' skills, talents and experiences was consistently high with many colleagues enthusing about high standards and inspirational teaching.

Some of the teaching is brilliant. [] Some inspirational teaching where they do simulations.

The depth of experience in the teaching staff is remarkable, nearly all on a second career, few are on a third career. We have some really knowledgeable staff who bring a good deal of industrial experience into what they teach.

My colleagues are stronger in their research and academic literature. I have colleagues who are up to date on the research.

Many colleagues were confident teachers with high levels of self-awareness:

*I'm good at resource investigation [] I like to network.
I communicate well with industry and end up with a more experiential set of modules and programmes as a consequence.*

*My strengths are coming from industry – automotive industry.
I'm credible in front of an audience.*

I bring in my own experiences and case-study learning

- Professional Relationships in Education

With learning and teaching forming the mainstay of the interviews, colleagues were keen to highlight the professionalism and collegiality of the team-teaching model:

The way that [one teaching group] is set up – they are a perfect team. They all teach together... team teaching and it works really well. Each teacher has different areas of responsibility.

Likewise, the fact that the students are taught in small groups of no more than 30 at a time was mentioned, with a particular emphasis on how this engenders positive working relationships amongst students:

On the teaching side we have several USPs, we do stuff in small classes, which allows good team working and syndicates.

Conversely, the professional learning relationships that lecturers have with students also proved to be an area that colleagues believed represented a positive aspect of the department:

It's pedagogically better to teach in small groups. The fact that we rarely have more than 30 students to teach is great for building learning relationships and engaging the students.

*The relationship between supervisor and student is a strength
We use people who know what they're talking about*

- **Scholarship in Practice**

A minority of those interviews relayed an awareness of the need for ‘evidence-based learning and teaching’:

I have done pedagogic research in the past a lot of my teaching reflects on my previous pedagogical research

My area of teaching is evidence driven. I look at two bodies of evidence. Student feedback and module reviews, chucking into Nvivo – the other is looking at journeys through the use of Moodle – trying to understand where students go, their journey

- **The value of industrial experience**

Whilst few colleagues were familiar with the need for scholarly based pedagogy, the value of teachers possessing industrial experience was widely discussed.

WMG needs to use externals, experienced people from industry. To develop materials and deliver lectures

The externals [from industry] bring a lot of experience. My modules have a lot of more external people than others. I get positive feedback from the students about this.

The value brought by external lecturers and project supervisors to the classroom and to individual students was discussed by the majority of participants; with industrial links and collaborations on a wider scale representing a significant part of what made department unique.

- Industrial Links & Collaborations

The 'real-life' context industrially based colleagues were able to provide in the classroom was perceived to be a key strength by the majority of those interviewed:

We have credible links into industry which enable us to contextualise what we do very well. We use people from industry a lot to make our teaching meaningful

Contacts in industry our one of our greatest strengths. We invite senior guest speakers from industry. All our tutors have a hybrid of academia and industry – this gives them credibility with the students

It's a true collaboration. Completely embedded. Both [companies]. We meet senior management every two weeks.

IMPLICATIONS FOR PRACTICE

This paper represents the tip of the iceberg in terms of the data collected. Engaging colleagues in reflective discussions about their own teaching is notoriously difficult (Clark & Andrews, 2017), hence the need to provide a non-threatening and confidential environment in which to conduct the interviews was of paramount. By focusing the conversation around three relatively simple questions the interviewer managed to convince colleagues to open up and so a depth of data was collected. Throughout the interviews the strengths and benefits that individual lecturers' bring to the classroom in the form of industrial experience and knowledge were continually extolled. Additionally, the need for professional learning relationships to be built and nurtured was also widely discussed with many colleagues inferring that they felt a strong sense of loyalty to both WMG and their colleagues.

The use of real-life industrial examples, case-studies and active learning approaches was identified as a key strength brought about by the fact that the majority of educators are on their second career, coming directly from industry into higher education.

Whilst the academia-industrial hybrid model of education is not unique to WMG, the continued provision of small group teaching and attention to individual students undoubtedly does give the department a distinctive organisational edge, providing students with a individualised learning pathway in which each one is supported in their learning and professional development.

CONCLUDING REMARKS

In conclusion, by focusing on positive areas of learning and teaching identified by colleagues this paper begins to touch upon the uniqueness of WMG itself. As stated in the introduction, the interviews took place at a time of uncertainty. Yet, despite this, the professionalism and dedication to teaching expressed by those interviewed was second to none. The challenge faced by management now, is how to take this forward and in doing so build on colleagues' dedication and determination to continue to provide world leading high quality learning and teaching.

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Engineering Chemical Engineering Lectures

Beneroso, Daniel

University of Nottingham

daniel.benerosovallejo@nottingham.ac.uk

KEY WORDS: Engineering Education, Professional Engineering, Teaching Practice, Process Engineering, Chemical Engineering

SUMMARY

Professional chemical engineering practice is supported by engineering methodologies that bring both process chemistry and process engineering approaches together. The ultimate goal for a practitioner engineer is to use those methodologies to define engineering challenges and their requirements, to research a solution by evaluating the available and estimated information, to make a decision based on specified credentials (e.g., safety, economic, and robustness criteria), and to finally communicate the solution to take forward. This article addresses how chemical engineering university teachers can use this underpinning engineering philosophy to their advantage to transform their usually abstract teaching sessions and to achieve higher satisfaction rates among students.

INTRODUCTION

The engineering lecture format has only changed in recent years and teachers have introduced more opportunities for student participation and interaction during the teaching sessions. In this regard, the active student-centred learning approaches have demonstrated to make a significant impact on the student learning experience (Morton 2007).

LITERATURE REVIEW

Engagement has a multidimensional character (Cirica and Jovanovicb 2016); usually three different dimensions are defined to analyse students' engagement: an emotional dimension (background and needs of the students towards learning); a cognitive dimension (motivations of the students to deal with new knowledge through strategy use and effort), and a behavioural dimension (persistence, attention and concentration during the lectures). These dimensions are interconnected within the learner (and sometimes overlapped); thus they do not work independently but they are malleable and dynamic (Fredricks 2004). Since a bidirectional interaction is usually established between the student and the teacher during the lecture, the latter can make an impact on how the former could strengthen their engagement dimensions.

CONTEXT: THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

The conventional teaching approach for many engineering courses is still focused on the delivery of – usually – an extensive amount of abstract content, where students do not have enough opportunities to be involved during the lectures. This issue has been extensively addressed in the higher education teaching literature and is related to the *engagement* (Morton 2007). Students who are engaged in the learning process are more likely to achieve the learning outcomes, and are generally more motivated, satisfied and self-confident when tackling with the module content (Fredricks 2004). In this article, a new and proven approach to teach core engineering modules at the University of Nottingham is presented as a way of *engineering* lectures involving highly abstract formulations.

DESCRIPTION OF INTERVENTION / PRACTICE

Chemical and Phase Equilibria (CPE) is one of the most conceptually challenging modules that students encounter on a chemical engineering course. This 10-credit module is delivered to 2nd year students from Chemical Engineering programmes during the autumn semester (~160 students). Although the material is quite abstract at times, the knowledge and skills learnt in

this module are applicable in the context of many of their engineering careers. Nevertheless, own observations indicate that students usually struggle to properly understand the fundamental concepts behind chemical and phase equilibria and hence, to engage with the module content.

EVALUATION OF INTERVENTION / PRACTICE

To evaluate the effectiveness of the proposed teaching approach compared to the conventional teaching scenario, results from the SEM (Student Evaluation of the Module) survey, along with student written feedback comments, are used. Particularly, the following questions were used as performance indicators of the proposed methodology, where students had to answer with a number between 1 (strongly disagree) and 5 (strongly agree):

- Question 1. The module has provided me with opportunities to explore ideas or concepts in depth
- Question 2. The module has challenged me to deliver my best work
- Question 3. The module has been well organised and has been running smoothly
- Question 4. Overall, I am satisfied with this module

The numerical average to each of the questions was converted into a percentage value for benchmarking purposes. 89 students responded to the SEM survey before the new teaching methodology was implemented (academic year 2017/18), whereas 71 did respond afterwards (academic year 2018/19).

DISCUSSION

Despite the fact that engineering student cohorts are usually large and diverse, humans are very similar in how they perceive, process, store and retrieve information (Lafferty and Burley 2009).

This means that teachers could use four universal learning principles (why, what, how, so what) as underpinning facts to create a 'template' to scaffold the new knowledge or skills to be taught.

Precisely, those four learning principles are inherently addressed behind each of the steps professional engineers follow in order to communicate engineering decisions: defining an engineering problem and their limitations (why), researching a solution (what) by evaluating the available information, and finally making a decision (so what). This fruitful synergy between learning and engineering principles is the foundation of the presented teaching methodology to engineer engineering lectures:

- Step 1: Problem identification and constraints (aka 'You are the engineer'): The first step of this teaching methodology is the answer to the principle 'Why?'. Why the taught concept is important to chemical engineers? Learning becomes easier if students are opened and ready to take in new info, and this is supported by emphasising the rationale of the delivered lecture. The answer to the why question allows students to perceive whether investing time and resources in their learning is worthwhile. For instance, when teaching sedimentation in a Particle Mechanics course, the lecturer could start the lecture by identifying a real-case problem (e.g., a grit removal process in a water treatment plant to separate sand from water) and by asking his students to come up with different limitations an engineer may encounter in such a processing unit (e.g., what if the sand size is very small?). Setting the scene leads to a potential engineering challenge (for instance, how the residence time of the incoming stream inside can be worked out to size the grit removal tank). At this point of the lecture, students are expected to utilise their prior knowledge on physics, and quite often guidance is required to drive the discussion.
- Step 2: Researching potential solutions (aka 'The fundamentals behind'): The second step of the proposed teaching methodology is the answer to the principle 'What?'. Such piece of information establishes a route for the learning of the students; therefore, being exceptionally clear and meaningful about the what becomes of paramount importance to increase the likelihood of learning the new concepts. To follow up using the same case scenario, when teaching sedimentation in a Particle Mechanics course, after having gone through the Step 1, the lecturer could specifically state what the potential solution

to remove sand from water is (e.g., a sedimentation unit) and what the physical and engineering fundamentals behind such a sedimentation unit are (e.g., a clear explanation of the settling phenomenon of a solid particle in a liquid, followed by an outline of the different forces acting upon the particle, this leading to a final forces balance to estimate the terminal velocity of such a particle).

- Step 3: Obtaining and critically analysing information (aka 'Calculation methods'): The third step is the answer to the principle 'How?'. Demonstration of how the engineering fundamentals established in the previous step can be applied greatly foster learners' performance. It is time for deciphering what the calculation methods are to solve the identified problem in the initial section. Outlining the instructions to use the Stokes' law for particle settling in order to determine the residence time of an incoming water stream into the grit removal unit may be a good example herein.
- Step 4: Making and communicating a decision (aka 'Solving the engineering issue'): The final step in this teaching methodology constitutes the answer to the principle 'So what?'. This is about putting all together and evaluating the initial problem shown in the teaching session. At this stage active, conscious attitude is considered to be essential for understanding and recalling the new learnt concepts, but this requires the student to be completely engaged in order to be effective. Teachers should be aware of different emotional intelligence techniques to keep the cohort under such state of mind, by being enthusiastic, friendly, and helpful and by providing meaningful in-class feedback.

The critical key for successful implementation of this teaching philosophy has been found to be to strictly follow the four-step structure in each and every one of the teaching sessions and tutorials, with no exception. The need to bring structure –e.g., in the form of the 4-step pattern described above– to what students consciously try to learn and recall is universal, regardless of their personal strengths or weaknesses (Colaso et al 2002), and this has been recognised by the students in the SEM survey (question 3, Figure 1) and in the form of written comments:

The lectures are amazing, clear and very well structured. I wish I could give any idea for improvement but these lectures are simply perfect

I greatly appreciate the thorough and painstaking work that Daniel has done on this important subject. His huge work and enthusiasm in Chemical and Phase Equilibria encourage and motivate us to study this subject. His lectures are very well-structured and clear. His presentations always contain lots of industrial correlation/problem/example, which help us to apply the knowledge in real world problem. Besides the lectures, the tutorials and calculation classes are extremely helpful, he always makes sure that everyone understands the topic

The implementation of this methodology has proved to be an outstanding success when implemented in different chemical engineering courses, especially in those containing a highly abstract formulation, such as Chemical and Phase Equilibria (CPE). Converting CPE abstract formulations into concrete engineering scenarios strictly following the addressed 4-step approach increased the overall learning satisfaction from 57% up to 86% in just one year (question 4 in Figure 1).

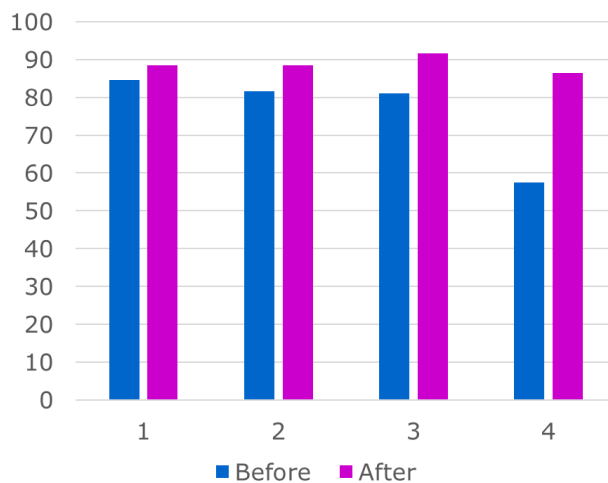


Figure 1. Student scores to the four SEM questions (%) before and after implementing the proposed teaching methodology

CONCLUSIONS & RECOMMENDATIONS

Even though students in large cohorts are highly diverse in many social, cultural and learning aspects, the reported teaching philosophy has been proved to be highly effective to engage a great majority of them. The use of both simple universal learning principles and an adequate teaching pattern in every teaching session have led to outstanding teaching scores based on student feedback.

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Towards Automated Learning Pathways for First Year Engineering Degree Apprentices via Threshold Concepts in Mathematics

Charlwood, Ismat Ali, Asad Kudar, Karen

WMG, University Of Warwick

i.s.charlwood@warwick.ac.uk

KEY WORDS: Threshold Concept; Mathematics; Education; Apprenticeship; Individualised Learning.

SUMMARY

This paper discusses pedagogic factors in the design of a digital learning resource for first year engineering degree apprentices, that can adapt to individuals' current learning to provide the scaffolding required for them to navigate successfully through the curriculum, with less lecture time and more seminar time.

Fundamentally this idea incorporates the 'flipped classroom' model where students are expected to arrive to class having watched video(s) of appropriate lectures before embarking on interactive tasks such as group work, discussion and exercises. The time freed up by not attending lectures is used to promote depth of understanding through discussion and interactivity (peer to peer and peer to teacher).

For degree apprentices on the Applied Engineering Programme (AEP) at WMG, University of Warwick, who attend part-time whilst also working, it is clear that students require more guidance and structure than exists in the standard flipped classroom set up. Watching videos of lectures in their own time is troublesome for several reasons, not least the tedium of watching

an hour long lecture if one is missing the fundamentals assumed in the lecture or equally, if one is waiting for something to be taught that is not already known.

In this paper we propose the use of automated individualised pathways through the mathematics content that is nuanced *enough* to provide support where required and point to next steps in learning where appropriate. We aim to make use of hinge questions (William 2018) to drive each student's individualised path through their engineering mathematics module according to their needs.

INTRODUCTION

The AEP is currently in its seventh year at the department of WMG. The course has steadily increased in student numbers with 36 in 2013 compared to more than 400 in 2019. The majority of AEP students are degree apprentices for whom work (at JLR, Aston Martin, Network Rail etc.) is interspersed with block-release study at the university. First year degree apprentices are required to attend six week-long blocks throughout the academic year, with each block consisting of a combination of lectures and seminars within these six discipline groups:

- Applied Engineering Design
- Electrical and Electronic Principles
- Engineering Business Management and Operations
- Engineering Mathematics
- Materials and Manufacturing Processes
- Static Mechanics and Energy Methods

Typically, first year AEP students have the following profile: male, white working class, low literacy level, grade B pass in A-level maths, reliance on mathematical procedures and/or

avoidance of conceptual models. Noticeably, even those students that do well on the engineering maths module, show signs of maths anxiety, low maths resilience and have a tendency to learn maths skills in isolation as evidenced by their lack of application of mathematical thinking to other disciplines.

In many respects, teachers of full-time engineering students share similar concerns although it is evident that a greater critical mass of degree apprentices exhibit concerning behaviours in maths learning and for longer.

Given that there are ever greater numbers of AEP students and that they manifest problem behaviours in maths learning, this paper sets out a new idea for creating a digital maths learning resource that aims to match resources to a student's individual needs. The objective of this ambitious *Engineering Mathematics Pathways* project is to find out what students already understand, to start them at the right level, and from there to adapt the route through the resources to create an individualised pathway that builds on previous understanding of threshold concepts and is able to direct them to the next steps in their learning.

In planning this resource, it is important to take into account how much contact time is also required and try to pinpoint what it is that face-to-face teaching and learning can add.

LITERATURE REVIEW

Land and Meyer (1995) coined the phrase 'threshold concept' to describe learning defined by these five characteristics:

- *Irreversible*
- *Transformational*
- *Troublesome*
- *Bounded*

- *Integrative*

Since this time they have refined their definitions such that differing levels of each characteristic may be present and sometimes some characteristics may even be absent (Shanahan et al, 2006), hence broadening further what might be classed as a threshold concept. Cousin (2006) goes further to explain the distinctive value of a threshold concept approach for curriculum design.

Although, on the whole, the threshold concept model has been largely accepted within the education community and for good reason, there is much in the definition that resonates with the authors as to what the best kind of learning feels like, there is also opposition to the idea (Rowbottom, 2007, O'Donnell, 2009, Salwen 2019).

The criticism lies mainly in the fact that the definition is so broad that it loses much of its focus and examples of key concepts that can / cannot be threshold concepts abound. A forceful argument from O'Donnell (2009) regarding the concept of *opportunity cost* faced by economics students shows the myriad ways the definitions break down for an agreed fundamental threshold concept within that discipline.

Despite strong personal experience transformative episodes in our own learning and that of our students, the authors have their own criticism of the threshold concept idea proposed by Land and Meyer, namely that each individual learner experiences understanding of concepts differently. Hence, it is near impossible to plan for such episodes to occur *en masse* in the classroom. In our opinion, teachers are best placed to provide a supportive environment and targeted guidance to get students to the point of and through transformative, irreversible, troublesome learning. However, a much more nuanced and delicate balance is needed to get the right level of challenge for each learner just at the point they are ready, whether they know it or not. We put forward that a teaching/learning schedule focused on tackling threshold concepts one after the other and expecting all students to be ready to receive the full transformative experience every time is not likely to be successful. This, in essence, transforms the 'threshold concept' from being universal (as proposed by Land & Meyer) to being more specific, temporal and at an individual level.

CONTEXT: THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

Part-time degree apprentices on the Applied Engineering Programme at WMG, University of Warwick, have struggled with mathematics courses. There are several reasons for this, and some of which tie up with similar experiences with traditional full-time engineering students whilst other factors are specific to them.

DESCRIPTION OF INTERVENTION / PRACTICE

The intervention we propose aims to provide a high quality virtual maths learning experience with just the right amount of teacher and peer contact time to maintain momentum and progress towards an individualised route through the maths content. Different routes through threshold and key concepts will be designed using hinge questions (William, 2018) to determine next steps in learning from a choice of support, assumed knowledge, extension, acceleration or enrichment.

We shall look at approximately 130 first year engineering degree apprentices and also a smaller group of thirty full-time engineering students without traditional maths qualifications. In the first instance we will trial different pen and paper exercises that focus on threshold concepts to test our understanding of how threshold concepts differ from key concepts. Later we will introduce some digital resources and trial our individualised flipped classroom supported by teacher and peer contact. We will look particularly at what face to face interaction provides that the digital classroom cannot (more nuanced individualisation is our guess).

EVALUATION OF INTERVENTION / PRACTICE

Students will be asked for their feedback throughout the learning via questionnaires and interviews to look for trends that might inform us about the strength and weaknesses of the proposed digital maths pathways intervention.

Our hope is that those students who have made the most and the least progress will also provide us with more detail in both these areas.

DISCUSSION

The individualised maths pathways resource aims to allow for more quality time spent face to face with teachers and peers so that more time is spent in active participation than passive listening. Less teachers contact time also frees up teachers to spend more of their time in preparation, resources creation and for providing quality feedback.

This intervention will be deemed successful if students' outcomes and attitudes in maths are positive and if they can be shown to be more positive than with traditional style maths passive lectures followed by tutorials/seminars.

One note of caution is that we are aware things may get worse before they get better so there may be some lead-time required in the model for students and teachers to learn to work in this new manner successfully.

CONCLUSIONS & RECOMMENDATIONS

Providing part-time engineering degree apprentices with an individualised route through maths resources should allow for students to make progress at the rate that is right for them and should provide the appropriate scaffolding needed to fill gaps in knowledge or extend to next steps or deeper understanding.

Understanding of threshold concepts along with key concepts, can be tested with the use of hinge questions – both of which are useful tools in designing this intervention.

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Improving Student Engagement in a Transnational Engineering Education Programme using Piazza

Ghannam, Rami^a Abbasi, Qammer H.^a Hussain, Sajjad^a

James Watt School of Engineering, University of Glasgow, UK^a

sajjad.hussain@glasgow.ac.uk

KEY WORDS: Engineering Education, Technology Enhanced Education, Teamwork, Collaboration.

SUMMARY

During the past decade, the UK has been expanding its educational programmes and services to universities located in Asia, South America and Africa. In fact, 75% of higher education institutes (HEIs) in the UK expect to develop transnational education (TNE) programmes within the next 3 years. However, there are challenges in ensuring that these TNE programmes are equitable to both sides of the partnership. In particular, the cultural background of the students must be respected. We are currently engaged in a TNE programme with China and we have noticed that student engagement in our first year Microelectronics course is low. We therefore trialled the use of a technology platform called Piazza to help improve student engagement. Based on statistical analysis of surveys that were completed by our students, Piazza has clearly demonstrated high student satisfaction. This can be attributed to the platform's ability to preserve the anonymity, harmony and face-saving characteristics expected from our Chinese students.

INTRODUCTION

TNE activity involves higher education (HE) institutes delivering educational services and programmes in another country. According to the British Council, TNE is defined as the

'provision of education for students based in a country other than the one in which the awarding institution is located'. UK TNE programmes are now established around the world, especially with HE institutes located in Malaysia, Singapore, China and the UAE. Such programmes further internationalise UK HE institutes, and at least 75% of UK institutes will be engaged in a TNE programme within the next 3 years.

Nevertheless, student engagement in Glasgow University's joint TNE programme with the University of Electronic Science and Technology of China (UESTC) has been a challenge, especially when cultural differences, language barriers and block-based teaching are considered. Moreover, we believe that active student participation during class discussions has been low due to a fear of public speaking or public rejection. These factors have contributed to limited interaction between staff and students.

To address this issue, we believe that cloud based platforms such as Piazza can provide the necessary space for students and staff to interact with one another. Such platforms support student anonymity and provide the necessary face-saving traits expected from our Chinese students. Furthermore, interaction takes place via text messages and "Chat" forums. Thus, interaction takes place in whole lines instead of one word at a time, which results in intermittent communication (Hartley et al., 2001, Hutchby, 2001). This delayed interaction provides time for students to translate their thoughts into phrases, which can be especially helpful for non-native English speaking students.

LITERATURE REVIEW

China's education system places greater emphasis on the teacher, who is considered the final authority in an academic discipline. This is different from "Western" culture, where students are encouraged to develop their own critical thinking skills. In fact, rigorous debate in Western academia is regarded as an indicator of a healthy academic community (Ingleby and Chung, 2009). Moreover, the literature provides a number of cultural factors that influence relationships between Chinese people (Fan, 2000, Hofstede, 2001). Factors such as face-saving, harmony, trust, collectivism and education strongly affect the way in which Chinese people interact with one another (Gu, 2009, Gu and Maley, 2008, Gu and Schweisfurth, 2006). Perhaps

due to these cultural factors Chinese students prefer not to engage directly in rigorous academic debate (Triandis, 1993) and prefer indirect communication, as suggested by Nguyen et al., (2009). Furthermore, Phuong et al (Mai, 2019) indicated that staff and students should refrain from negative criticisms during group discussions. Therefore, we believe that social engagement platforms such as Piazza are particularly suited to the cultural background of our Chinese students, since they can turn their online discussion forums into active learning environments.

CONTEXT: THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

During the delivery of our Microelectronics module, we noticed that student engagement is low. We believe that the cultural differences, language barriers and the nature of TNE block teaching have all contributed to this low student engagement. In an effort to improve student engagement, the aim of our intervention was to trial the use of a cloud based online platform called Piazza.

DESCRIPTION OF INTERVENTION / PRACTICE

Our intervention was carried out during one semester of the Microelectronics course. A total of 293 undergraduate students enrolled in Piazza. We introduced students to the platform during one of the lectures and we monitored their online engagement. Students were encouraged to post any queries related to the lecture or laboratory materials, which were then answered by the instructor, the GTAs or other students. This process enabled useful peer to peer discussions. Similarly, teaching assistants and instructors moderated the discussions to ensure that queries were responded to in a satisfactory manner. To investigate the effectiveness of Piazza, we monitored the number of queries posted by students, the percentage of answered questions and the response time to student queries. We also carried out a survey with 10 questions. A total of 23 students completed the survey, which is a response rate of approximately 8%. According to (Nulty, 2008), this is the minimum response rate deemed

acceptable for a class size of 300 for a 10% sampling error and 80% confidence level. Results of our intervention are provided in the next section.

EVALUATION OF INTERVENTION / PRACTICE

A snapshot showing the number of active users within the semester is shown in Fig. 1(a). Similarly, Fig. 1(b) shows the number of questions posted each day. Both figures show that students are more active during certain weeks in comparison others. This observation is perhaps due to the nature of our block-teaching, whereby students are more likely to study intensively during a teaching block. Consequently, the graphs provide insight for instructors to design learning activities during the nonteaching blocks of a TNE programme. This ensures students engagement throughout the semester.

According to responses from the completed student surveys, more than 72% of students positively rated their Piazza experience, as shown in figure 2. Specifically, 50% of students agreed that Piazza improved their understanding of the lecture materials, while 33% of agreed that the quality of their lab project improved using the Piazza forum.

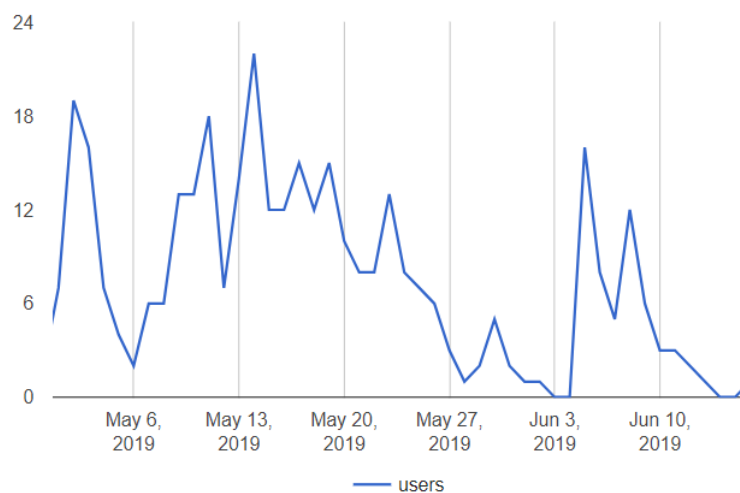


Fig. 1: (a) Number of active users on Piazza each day.

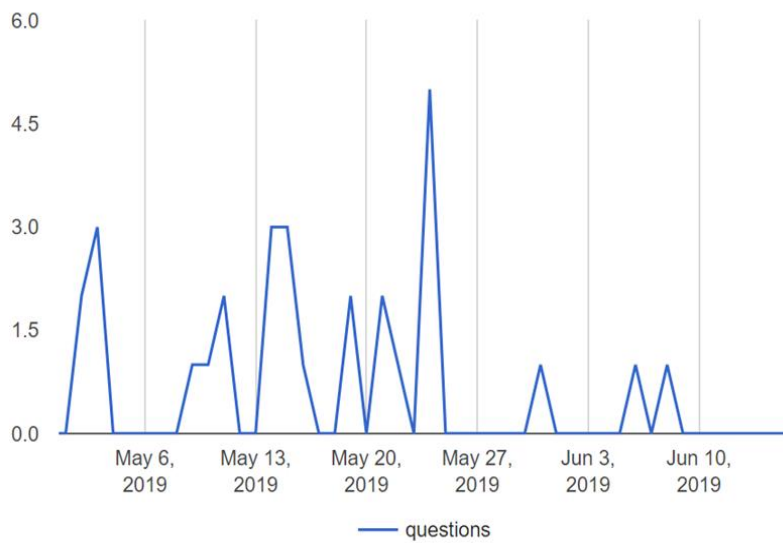


Fig. 1: (b) Number of questions asked on Piazza each day.

Similarly, students were asked about the least favourable Piazza features. According to their responses, students disliked the weak support received from their peers, as shown in fig 2. Currently, only 25% of student queries were answered by fellow students.

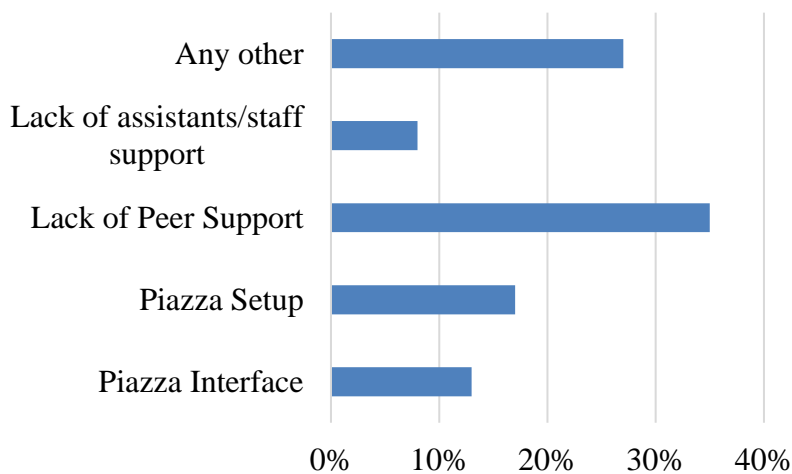


Fig. 2: Students responses to the least favourable features in Piazza.

According to student responses, Piazza is a very useful learning resource, as mentioned by 33% of students. Other useful features include the quick response time to student queries, as shown in figure 3. In fact, the average response time was less than 30 minutes. Moreover, 14% of students liked being anonymous while posting or responding to questions on Piazza.

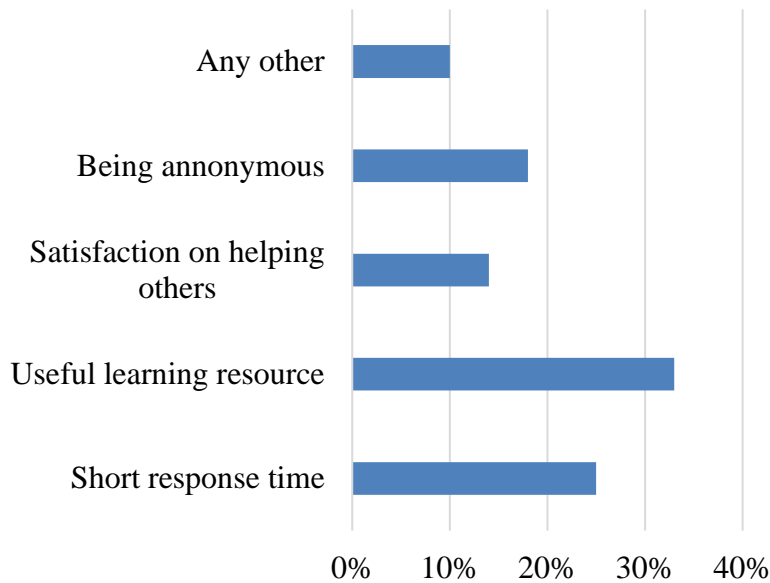


Fig. 3: Survey results regarding Piazza's most useful features.

A summary of the main Piazza statistics is provided in table I. Remarkably, almost 95% of student queries were answered within the semester.

Piazza Feature	Number
Total number of questions posted on Piazza	57
Number of answered questions	54
Total number of contributions (questions, responses and comments)	393
Number of questions answered by students	14

Table I Summary of engagement statistics using Piazza.

DISCUSSION

We analysed student engagement using the Piazza platform. Our results confirm that students interacted well with the platform, since there were a total of 393 contributions throughout the semester. The majority of students (33%) found Piazza as a useful learning resource that helped them understand the teaching materials better. The second most popular feature was the fast response time to student queries, which was less than 30 minutes, on average. Our teaching

assistants and students maintained this quick response time, since they took “satisfaction [from] helping others”. In fact, this was the third most popular feature of the platform. Perhaps this could be attributed to the collectivist and Confucianist background of our transnational Chinese students

According to the surveys, the collaborative features of Piazza enabled students to improve the quality of their laboratory reports and helped them understand the lecture materials better. Furthermore, almost 95% of student queries were answered within a response time of less than half an hour. This is a remarkable achievement, given the large cohort of students (293) and the 7-hour time difference between Glasgow University and UESTC. This is particularly important, since students typically start posting questions near a submission deadline or before an exam date. However, students complained that peer support from fellow students was low. This was reflected from Piazza, where only 14 out of the 57 questions (approximately 25%) were answered by students. To overcome this, we suggest increasing the number of teaching assistants. While there has been a distinct improvement in student interaction and a positive student experience, we would like to extend this work and monitor the change in grades that this intervention has caused. We also endeavour to encourage more students to take part in our surveys, since the response rate was currently limited (approximately 8%).

CONCLUSIONS & RECOMMENDATIONS

We carried out an investigation using the Piazza platform to test whether student engagement can be improved in a first year undergraduate engineering course called Microelectronics. According to our results, student engagement is greatest during the teaching blocks of the TNE programme. The platform has enabled students to understand the lecture material better. It has also helped them write better laboratory reports. Moreover, 95% of student questions were answered within an average time of 30 minutes. However, students felt disappointed that few of their fellow colleagues took part in answering their queries (only 25%). Consequently, we aim to encourage more student contributions and greater peer support by offering rewards or incentives to students. In addition, we will investigate whether increasing the number of teaching assistants will reduce student response times to queries.

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Comparing Active and Didactic Pedagogies in Electronic Engineering

Jackson, Noel Robin

Department of Electronic Engineering, University of York

noel.jackson@york.ac.uk

KEY WORDS: Flipped, Active, Engineering Education, Large Cohort, Curiosity.

ABSTRACT

This paper summarises the output from doctoral research exploring the viability of employing active rather than passive teaching pedagogy for large engineering cohorts in HE. It builds from the model of 'curiosity-based learning' as previously deployed by the author for small engineering groups and utilises the 'flipped classroom' model as the choice of active teaching pedagogy and standard lecture-based didactic teaching for the passive approach. The categories tested included the importance of knowledge, skills and improvement, preferred learning and thinking style, self-esteem and self-efficacy.

Outputs indicated no support for any changes to a learner's preferred thinking style but some support for; an impact on a learner's desire to learn; a learner's preferred learning style being affected; raised belief in a learner's current abilities (self-esteem); improved learner's self-efficacy through active teaching. However, some learners are affected by the amount of additional study needed to prepare for lessons. The study found that females showed more realism in their capabilities, willingness to take on more responsibility for their learning and that students plan, organise and question more effectively when exposed to active teaching. These results have implications for choice of pedagogical model, curricular design and indicate both the limitations and potentials of extending active teaching and learning from smaller to larger cohorts.

INTRODUCTION

The research investigated whether a flipped classroom active teaching approach, used in general education (Tucker, 2012) and also in higher education (HE) (Zappe et al., 2009), was more beneficial to engineering students than a traditional didactic approach. Compared to traditional teaching, the flipped classroom requires pre-reading of materials, consolidated in subsequent exploratory, discursive sessions. This action-based research, derived from the findings of a small-scale pilot (n=12), focussed specifically on changes in student attitude and motivation between cohorts of >30 students. The research was modified for a HE large classroom setting due to lack of research into the effects of flipped classroom approaches for larger engineering student cohorts (Toto and Nguyen, 2009). A further review of research identified texts on the importance of evidence-based research in HE (Clark, 2009; Clark and Andrews, 2014) and some studies into flipped teaching outcomes with 30+ engineering students (Reidsema et al, 2017; O'Flaherty and Phillips, 2015).

LITERATURE REVIEW / RATIONALE

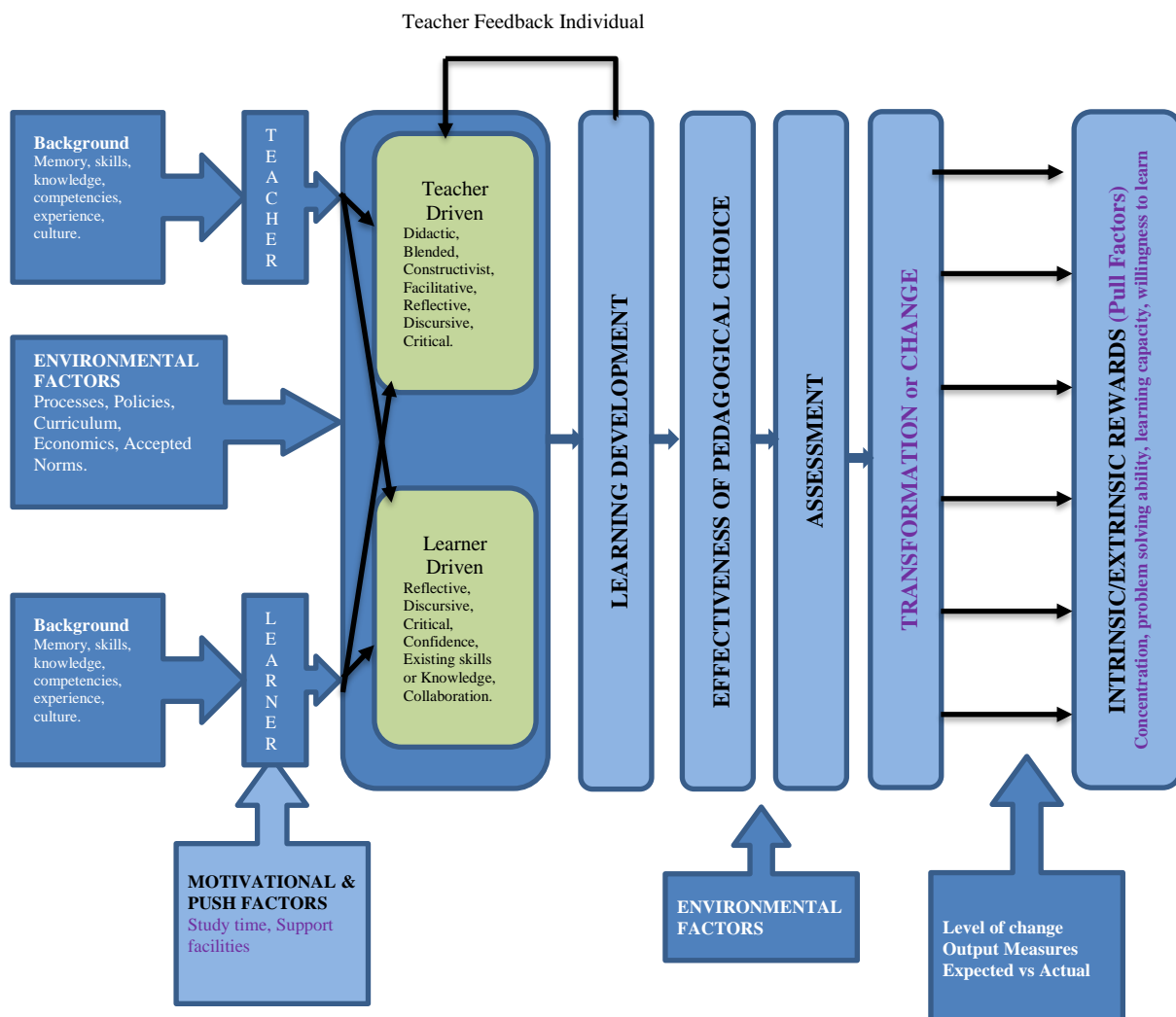
The theory underpinning didactic teaching focusses on discovery and application, teaching learners 'what' not necessarily 'how' to think (Fry et al., 2003) lending itself to a lecture-based teaching approach.

Theories of active teaching claim that it encourages students to improve their own knowledge, potentially adding to their workload (Lombardini et al., 2018). It is arguable that the early thinking on scaffolded/collaborative learning (Wood et al., 1976; Vygotsky, 1978) was the catalyst for development of more active approaches. Through pre-reading needed for flipped classroom teaching (Lage and Platt, 2000), Bishop and Verleger (2013) propose that learners use reflection rather than relying on memorising facts and Alexander (2013) felt that dialogue actually encouraged learners to investigate issues. Sheppard (2013) confirmed that universities allow teachers to use their own preferred teaching style/s thus a mix of approaches would be appropriate to support initiatives from other stakeholders e.g. The Institute for Engineering

Technology (IET, 2016) who would like more transferrable skills to be developed (see SALEIE, 2016).

The research developed a pedagogical model incorporating learning ‘pull’ and teaching ‘push’ factors (Fig 1) from which new theory might develop around transformative teaching (Mezirow, 2003). Benziger (2013) felt that learners have a preferred or dominant thinking style thus a single teaching approach is unlikely to be suitable for all engineering learners. Whilst learning and thinking styles theory have developed at the same time, the reality of learning styles is debateable (Willingham et al, 2015). Cuevas (2015) reviews each of the main learning styles models concluding that none of them have any relevance to learning or teaching. Later research into the impact of learning styles using a flipped classroom (Nwokeji and Holmes, 2017), found some differences attributable to the teaching approach when respondents were grouped into learning styles (Visual, Auditory and Kinaesthetic or VAK) preferences.

Figure 1 – Model for Methodological Choice in Education



AIM AND OBJECTIVES / RESEARCH QUESTION(S)

Measuring the impact of an active teaching approach compared to a didactic teaching approach in electronic engineering students to inform the design of teaching materials was the primary aim. The main research questions were:

- The flipped classroom – does this dialogic/active teaching approach lead to a change in a learner's preferred learning/thinking style compared to a passive approach?
- Does a flipped classroom approach enable students to be more confident in taking responsibility for their own learning and achievement compared to a passive approach?

The above research questions were addressed through 5 discrete hypotheses:

H1 – An active teaching approach impacts positively upon a learner's desire to learn when compared to a passive teaching approach.

H2 – A learner's preferred learning style can be affected by being exposed to an active teaching approach.

H3 – A learner's preferred thinking style can be affected by being exposed to an active teaching approach.

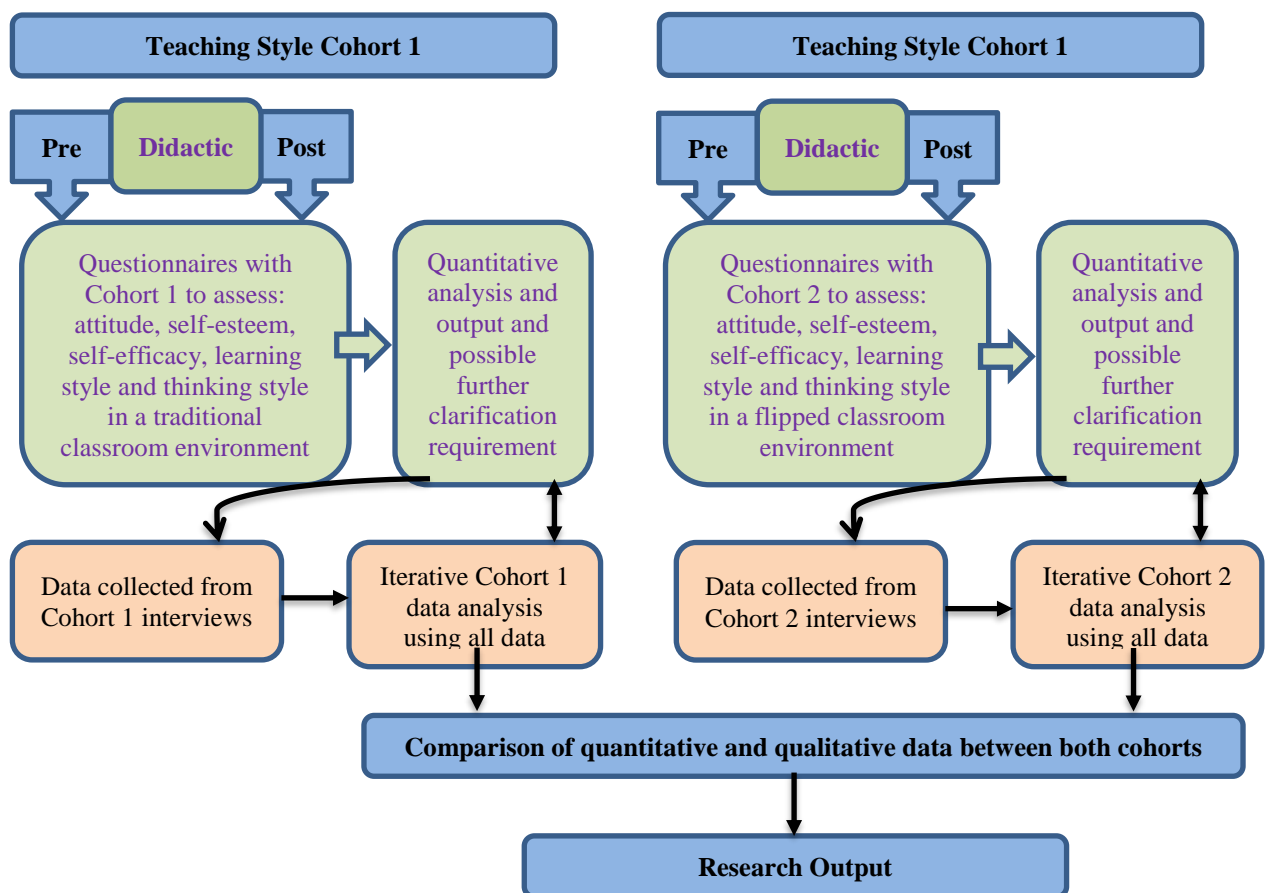
H4 – A learner's belief in their current abilities (self-esteem) is affected by being exposed to an active teaching approach.

H5 – The learner experiences a rise in their level of self-efficacy and takes more responsibility for their own learning when exposed to an active teaching approach.

METHODOLOGICAL APPROACH

The research studied two undergraduate and two postgraduate cohorts utilising passive teaching with the first cohort (2016-17) and active teaching with the second (2017-18). This two-cohort methodology meant questionnaires were completed pre and post the delivery of taught material and qualitative interviews were held post questionnaire analysis. The research can thus be considered as a quantitatively dominant, explanatory and sequential mixed methodology (Fig 2) that sought to explain the impact of actions taken by the educator in the course of pedagogical practice.

Figure 2 – Research Method



THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

The problem stems from very few instances of research into large engineering cohort teaching (>30 students) using the flipped approach to inform pedagogical design/delivery.

The limitation of this research was that there was no direct comparison between modules delivered by different teachers so the intervention only compared the researcher's teaching in successive cohorts.

KEY FINDINGS

H1 – An active teaching approach impacts positively upon a learner's desire to learn when compared to a passive teaching approach. Outcome: partially rejected.

H2 – A learner's preferred learning style can be affected by being exposed to an active teaching approach. Outcome: partially supported.

H3 – A learner's preferred thinking style can be affected by being exposed to an active teaching approach. Outcome: rejected.

H4 – A learner's belief in their current abilities (self-esteem) is affected by being exposed to an active teaching approach. Outcome: partially supported.

H5 – The learner experiences a rise in their level of self-efficacy and takes more responsibility for their learning when exposed to an active teaching approach. Outcome: supported.

Table 1 – participant information

Participant type	Cohort 1 (Didactic approach) Responses received Sept to Dec 2016		Cohort 2 (Active approach) Responses received Sept to Dec 2017	
	Pre-Teaching	Post-Teaching	Pre-Teaching	Post-Teaching
Undergraduate	n = 33	n = 33	n = 91	n = 50
Postgraduate	n = 34	n = 32	n = 53	n = 50

DISCUSSION

H1 – Desire to Learn. Outcome: partially rejected.

Respondents agreed that whilst they had always felt knowledge to be important, active teaching had reinforced that view. Active teaching might impact positively when stressing key facts but the same was not true when learning new skills where there was no supportable evidence of any impact. All students acknowledged that certain skills are key but that active teaching had only moved their focus rather than improved their views, reinforcing rather than impacting upon their desire to learn. This is surprising as engineering students would be expected to desire practical experience (Kerr, 2015). Gender differences show that active teaching may be more effective in stimulating curiosity and a willingness to question in females.

H2 – Preferred learning style. Outcome: partially supported.

Using the VAK construct (visual, auditory, kinaesthetic) to measure learning style changes (Dunn, 1990) most cohorts showed a slight shift in learning style preference towards a kinaesthetic style and at interview felt that active teaching has to be carried out in the correct context. Interestingly this contradicts the outcome discussed above where little supportable evidence emerged for a rise in a student's willingness to learn new skills. This may be a key finding for engineering educators since an active teaching style was thought by the researcher to have more impact and thus challenges earlier findings in support of links between teaching style and learning style preference (Felder and Silverman, 1988). It supports Clark's (2009) research which found these links to be more relevant for improving teaching practice rather than affecting learning style.

H3 – Preferred thinking style. Outcome: rejected.

Gregorc's (1984) categories Concrete Sequential (CS) – realist; Abstract Sequential (AS) – theorist; Abstract Random (AR) – reflectivist and Concrete Random (CR) – experimentalist were used to measure thinking style. However, no findings from quantitative analysis or qualitative responses show a definite change in either undergraduate or postgraduate thinking style preferences.

H4 – Belief in their current abilities (self-esteem). Outcome: partially supported.

Active teaching may enable better planning, organising, questioning and responsibility in engineering learners and is potentially a key finding given that it augments and improves their confidence in applying these skills. However, there is also an indication that competing pressures on student time may have affected active learners and might be an unintended effect of active teaching and is also found in other large cohort studies (Gullayanon, 2014; Lombardini et al, 2018). One very interesting outcome shows that females are more affected by active teaching than males and this is an area worthy of further research given the context of females in engineering.

H5 – Raised levels of self-efficacy and taking more responsibility for learning. Outcome: supported.

There is evidence of more self-reliance in all students when exposed to active teaching, supporting the findings of Ojunugwa et al. (2015). Interview responses from active learners indicate that questioning, discussion and pre-reading are now very important to them, giving them confidence to discuss issues without fear of ridicule (Alexander, 2013). This is vital for engineers because they need to be curious in order to solve problems and plan appropriately. Females exposed to active teaching show more realism and take on more responsibility for their learning, contradicting Huang (2013). Students from actively taught cohorts are more motivated and will 'push' themselves more to achieve (Concannon and Barrow, 2010).

REVIEW

On reflection, the research indicates overall support for the use of flipped classroom techniques. However, it has not successfully proven the use of such techniques to be suitable for all situations. Active teaching can be useful for certain types of knowledge transfer activities, even in large class scenarios supporting Reidsema et al (2017).

Issues included the research taking too long - might have been better focussed through qualitative measures or teaching modified during the timespan of a single module to identify any impact on learners as the teaching style changed.

Data analysis was tedious, the majority of tests showed data to be non-normally distributed limiting the analysis to non-parametric measures. With more respondents this may have been avoided and is a key learning point.

The research concentrated on assessing competences and did not attempt to measure summative outcomes for students. A final outcomes analysis may have uncovered further indications of the effectiveness of flipped classrooms.

CONCLUSIONS & RECOMMENDATIONS

There is good support for active teaching being more effective in increasing self-efficacy (Abeysekera and Dawson, 2015), especially in females, reasonable support for it effecting a rise in self-esteem (Ojunugwa et al., 2015) and some support for it having an effect on learning style and planning (Felder and Silverman, 1988). There is less support for there being an impact on a learner's desire to learn (Jackson and Ward, 2012; Reidsema et al, 2017) and no support for it making any difference to the way a learner thinks about their learning (Gregorc, 1984).

The research has not yet generated a new pedagogical model but key additional elements identified for incorporation into any new model include gender-based differences. The areas for elimination from future models include ethnicity, age-related differences, learning style preference and thinking style preference.

Further studies are recommended into the following:

- The negative effects of an active teaching approach;
- An appropriate method of researching gender differences in engineering education;
- A gender-based study into the effect that active teaching has in stimulating curiosity in budding engineers;

- A specific research looking into the development of critical thinking through active teaching;
- Identification of a likely measure of the effectiveness of active teaching in terms of class size.

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Design of an Industry-Focused Introductory Programming Course

Yang, Jianhua^a Azmat, Freeha^a Shore, Diana^a Wanjir, Maxwell^b Gnafakis, Panagiotis^b

WMG, University of Warwick.^a Jaguar Land Rover.^b

Jianhua.Yang@warwick.ac.uk

KEY WORDS: Work-Based Learning, Introductory Programming, Degree Apprenticeship, Course Design, Digital & Technology Solutions (DTS)

SUMMARY

In the UK a new type of degree has recently been introduced, the Degree Apprenticeship. This imposes new challenges as well as opportunities for designing and teaching programming courses. In this paper, we present the design of an introductory level programming course for the Digital and Technology Solutions BSc degree at the University of Warwick. The course has a tight industry-focus, making use of work-based projects to link learners with university academics and employers, and to motivate learners to learn programming concepts and skills by doing work-based projects. In this paper, we present and discuss the options available to us in terms of course delivery, assessments, student engagement, virtual learning spaces, language choices, as well as the rationale behind our choices. The first round of teaching is still in progress and we anticipate to see significant differences in terms of learning that benefit both learners and employers, compared to formal university education.

INTRODUCTION

Degree Apprenticeships (DAs) are a new type of programme offered by some universities. DAs are different from work-based learning in that apprentices are full-time employees of a company, and at the same time, registered as part-time students in a university. DAs are also different from traditional part-time degrees as employers play an important role in developing the degree

programme. One example of the DA is the Digital and Technology Solutions (DTS) BSc degree offered at the University of Warwick. In this paper, we present the design of an introductory programming course for DTS. The course is learner-centred aiming to build a solid knowledge of programming and algorithm concepts. It is also facilitated with and specific programming skills and behaviours targeting immediate and future work competencies.

LITERATURE REVIEW

There's a distinction between work-based learning (WBL) and formal university education. WBL normally takes place in the workplace. It is based on learners' existing knowledge and introduces new knowledge in the context of working environments. It is tailored to fit learners' individual circumstances and provides personalized feedback and tutorials (Ball and Manwaring, 2010, Nixon et al., 2006). In comparison, formal university education takes into account of subject differences and tries to bridge those differences and systematically deliver knowledge (Lea, 2015). However, employers often find that fresh graduates from universities are not equipped with up-to-date skills they require. The gap between WBL and formal university education can be filled by carefully designed courses connecting learners, employers, and universities. This is also the aim of DAs.

Programming language education has established as a subject of pedagogical research. Traditional computer science educators focused on human cognitive theories and emphasized pattern-based approaches (Caspersen and Bennedsen, 2007), while more recent studies suggested the use of modern tools and agile-based methodologies. For example, Raj et al. (2018) and Brown and Wilson (2018) showed that live coding, writing actual code during class as part of the lectures, is effective when teaching programming. Brown and Wilson (2018) also suggested that the use of pair programming and peer instructions, which are also agile methodologies used in software engineering. In pair programming, two programmers share one computer, one does the typing and the other offers help. Pair programming encourages communication, and make learning happen on both parties. These different techniques increase learners' perception and level of engagement. However, one important aspect that is missing is motivation. It's a common practice for technical degrees at the university level that programming languages are taught first of all, such that these languages can be used as vehicles

for advanced subjects such as image processing. However, before reaching relevant subjects, few learners realize the relationship between programming skills and specific subject knowledge. On the other hand, in the business world, programming languages such as Python can be a really useful tool even at the beginner level. The immediate benefit to the employers can also be served as a huge motivation for learners from an industry background. Unfortunately, studies of modern programming language education in the context of WBL are sparse (Medeiros et al., 2018, Robins et al., 2003).

CONTEXT

The Institute for Apprenticeships & Technical Education (IATE) standard for digital and technology solutions professional ST0119 (2019) defines a few core Knowledge, Skills and Behavioural requirements (KSBs). Besides, depending on specific job roles e.g. Software Engineer, some other requirements are further specified. The KSBs relevant to programming education are summarized in Table I. These KSBs provide guidelines when we designed the programming course.

Table I Knowledge, skills, and behavioural requirements (KSBs) concerning programming education as specified in the Institute for Apprenticeships & Technical Education standard (2019).

	Core	Software Engineer Specialism
Knowledge	<ul style="list-style-type: none"> • How to design, developing, testing, correcting, deploying and documenting software systems • How teams work effectively to produce technology solutions. 	<ul style="list-style-type: none"> • How to apply software analysis and design approaches. • How to interpret and implement a design. • How to perform functional and unit testing. • How to use and apply the range of software tools.
Skills	<ul style="list-style-type: none"> • Analyses business and technical requirements. • Designs, implements, tests, and debugs software. • Configures and deploys solutions to end users. 	<ul style="list-style-type: none"> • Undertake analysis to produce robust software designs. • Produce high quality code with sound syntax. • Perform code reviews, debugging and refactoring. • Test code to ensure that the functional and non-functional requirements.
Behaviour	<ul style="list-style-type: none"> • Fluent in written communications. • Makes concise, engaging and well-structured verbal presentations. • Able to give and receive feedback and incorporate it into own development. • Apply structured problem solving techniques. • Conduct effective research using literature and other media. 	

Figure I shows that there are large overlaps between knowledge, skills, and behaviour, as in practice quite often some activities concern all three.

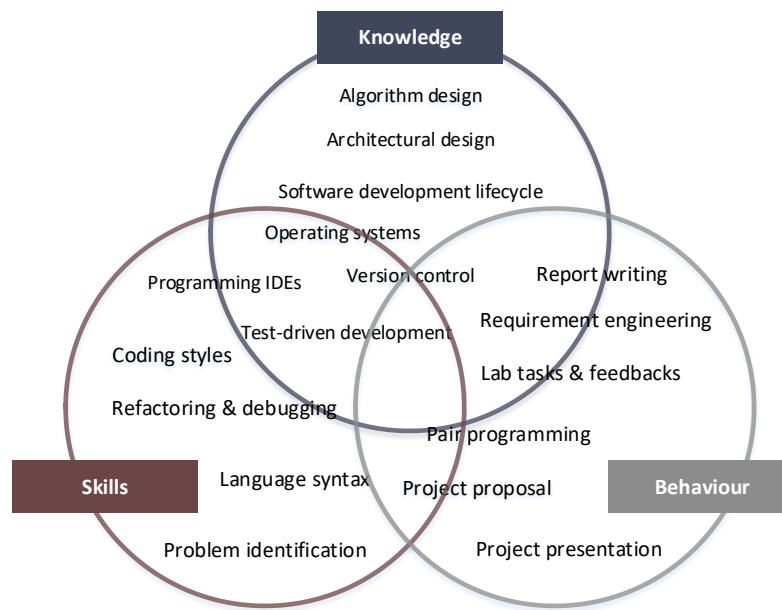


Figure 1 Indicative contents and activities in the course.

COURSE DESIGN

The course design we present here is a result of academics at the University of Warwick working closely with business partners at Jaguar Land Rover (JLR). As the first step, elements of the IATE standard were mapped to indicative contents and activities as shown in Figure 1. It is evident that in practice there are no clear boundaries between those KSBs. For example, test-driven development can be knowledge about integration test design. Meanwhile, it can also be skills about language-specific test libraries, or behaviour of how often a coder does testing. As it is an introductory course, the emphasis was put on skills and behaviour instead of knowledge.

Overall, the course delivery takes an iterative approach as illustrated in Figure 2. One iteration starts with stage 0 pre-sessional activities, ranging from exploration to exploitation, from the reading list to online video tutorials. Academics then give formal delivery and live coding, emphasizing those points that learners have difficulties with. This is then followed by interactive activities such as pair programming and project presentations. Raspberry Pi and Arduino are also used as tools to enhance engagement. Learners are encouraged to communicate with each other to discuss their understanding and share progresses. Stage 4

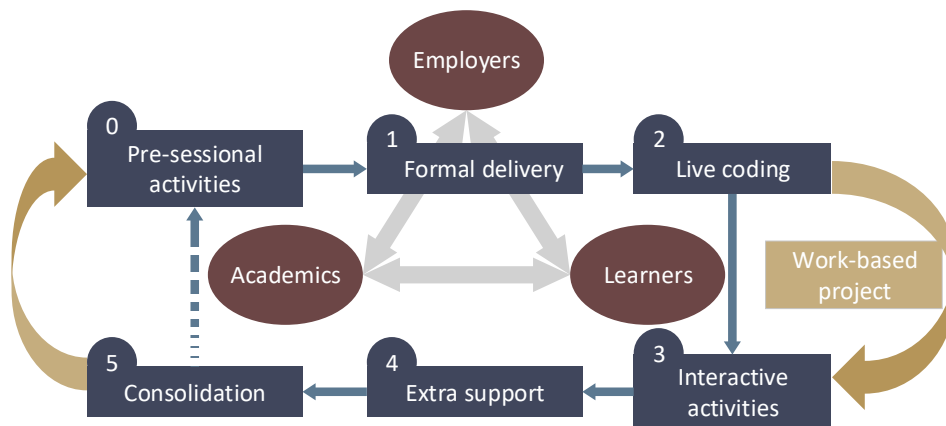


Figure 2: Iteration in Course Delivery

Delivery takes an interactive approach starting from pre-sessional activities to consolidation for one complete cycle. It is learner-centred and connects both academics and employers. Work-based project provides an important motivation throughout the delivery. Extra support is more individual-oriented, giving learners the necessary support they require. In the final consolidation stage, learners are given ‘programming challenges’. These challenges are questions without answers and require learners to have a sound understanding of the KSBs delivered in the current cycle to complete.

Attention was paid to work-based project (WBP) formation and solving to address the motivation issue. In particular, we designed the assessment to be a WBP. Learners are free to choose their projects, but they need to deliver project outcomes using knowledge and skills developed during the course. The projects are monitored and discussed thoroughly with university academics and employers to make sure that they are specific enough to solve genuine business problems and at the same time, flexible enough to suit the current level of study. These projects are assessed using the actual coding and written reports against the KSBs delivered during the course. We anticipated that this creates the value for the employers, and hence provides the necessary motivation for learners.

DISCUSSION

Any course design has to take into account the types of learners. In the DTS cohort, a large portion of the learners have been out of full-time education for a considerable amount of time and have no experience of programming. On the contrary, many of them have been exposed

to programming languages of various kinds. This is not normally seen in formal university education. Thus, a particular challenge of the design was to provide the flexibility of stretching to suit individual learner's circumstances. WBPs provide this flexibility by allowing learners to define their own tasks and objectives. WBPs also provide sufficient motivation by giving learners opportunities to contribute directly to their employers.

The main programming language used in the course was Python. We chose Python because the scripting mode makes it excel in the business world, in addition to its beginner friendliness and clean syntax. In the literature, it is believed that a single programming language should be taught at once instead of two or more languages (Brown and Wilson, 2018). We agree that for beginners mixing two or more languages can cause confusion. However, in reality, there is no one language that fits all purposes. For example, apprentices working in electrical systems will prefer to learn C++ to manipulate memory on an electronic control unit (ECU). Considering this, we also incorporated C++ in the course. C++ language was put towards the end, at which point, learners are already confident with programming concepts and can understand syntax differences.

Even though the current course targets programming education, it crosses the border between programming and software engineering (SE). For example, work-based problem formation and solving involve SE topics such as requirement engineering and architectural design. We believe that it is beneficial for the learners to be exposed to these methodologies at an early stage. Because this can help learners to identify problems from a much broader perspective, and gives them the capability to plan solutions without conducting coding. Besides, for work-based projects to stimulate learning, learners must not be over-pressed. SE methods can help learners to easily oversee the progress of their projects, and reduce unnecessary pressure.

CONCLUSION

In conclusion, we believe that motivation plays an important role in programming education. The newly introduced DA links apprentices with universities and employers and provides an opportunity to address the motivation issue that is often absent in formal university education. Using work-based projects, the introductory programming course presented here is learner-

centred, combining a range of engagement activities and techniques. It is also industry-focused, considering business needs and addressing business problems. Overall it aims at better learning by doing in an individual-relevant environment. The first round of teaching is still in progress, and there is a high level of engagement. By the end of the teaching, we will evaluate the student experience and refine and revise our approach.

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The T-CHAT Teaching Approach: An Introduction

Mäkiö-Marusik, Elena^a Azmat, Freeha^a Ahmad, Bilal^a Harrison, Robert^a Colombo, Armando
Walter^b

WMG, University of Warwick^a; University of Applied Sciences Emden/Leer^b

E.Makio-Marusik@warwick.ac.uk

KEY WORDS: Engineering Education, T-CHAT Teaching Approach, Project-Based Learning, Competencies, Learning Activities, Assessments

ABSTRACT

Society and businesses are formulating growing demands on today's engineers. To be employable, engineering graduates need to have a multidisciplinary view on their profession and possess a broad range of knowledge, skills, and competences for engineering work and career. Academic institutions in their responsibility to society, industry, and engineering students developed educational approaches that aim to facilitate student learning and skill development. This paper introduces a new task-centric holistic agile teaching approach which is being developed as part of a PhD study into engineering education. Termed the T-CHAT the study is a response to the growing demands of industry and society to critically examine how disciplinary, methodical, social and personal competencies are taught and developed in engineering students. T-CHAT integrates five pedagogical approaches: 1) perceptual learning; 2) project-based learning; 3) problem-based learning; 4) research-based learning; and 5) face-to-face teaching. This paper deals with the project-based learning pedagogical approach and briefly discusses 1) learning activities that support it, 2) assessment tasks that are conducted, and 3) competencies that are developed.

INTRODUCTION

Engineers of today are required to fulfil the growing demands formulated by society and industry. They are expected to possess not only profound disciplinary knowledge, but also a range of methodical, social and personal competencies (Male 2010; Mäkiö-Marusik 2017). Academic institutions have responded to these demands and reformed engineering education to improve the quality of their modules and programs and applied novel educational approaches and educational innovations (Crawley et al. 2014; Kolmos 1996; Mills & Treagust 2003). One of the newly developed approaches is the task-centric holistic agile teaching approach T-CHAT (Mäkiö et al. 2016). T-CHAT addresses improvement of methodical, social and personal competencies of students along with the development of disciplinary knowledge and skills. The idea of T-CHAT is to use five pedagogical approaches (i.e. 1)perceptual learning, 2)project-based learning, 3)problem-based learning, 4)research-based learning, and 5)face-to-face teaching) and combine them with the aim to make learning more efficient by varying the pedagogical techniques in an agile manner (according to the changing needs of students).

BACKGROUND

The innovative pedagogical approaches, for instance problem-based learning (PBL) and project-based learning (PjBL), are increasingly used in delivering engineering modules. These and other single approaches can be combined in an integrated educational approach to achieve additional educational benefit. For instance, a combination of PjBL and PBL was successfully implemented for engineering curriculum at Aalborg University (Kolmos et al. 2004) as well as in several courses within the civil engineering program at Monash University (Mills & Treagust 2003). Another distinctive approach, Conceive–Design–Implement–Operate implements discipline-led learning and PjBL/PBL at the curriculum level has been adopted by over 100 member universities all over the world (Crawley, 2014).

The proposed new approach, T-CHAT, is a task-centric holistic agile pedagogy for use at the modular level. It combines five single approaches in an attempt to address the development of a broad variety of competencies required in engineering graduates (Mäkiö et al. 2016). Another attribute of T-CHAT is a task that focuses on a real-life problem and often emphasizes

interdisciplinary view on an issue within the discipline. The approaches that form T-CHAT are briefly described below.

Perceptual Learning is a conception and a teaching strategy that was developed for teaching physics (Kurki-Suonio 2011). It is based on the idea that “perception plays a fundamental role in all learning” and is an intuitive, non-conscious, process of creating meanings based on empirical observations and interpretations. The concept of perceptual learning serves as theoretical background for T-CHAT approach.

Project-Based Learning organizes students’ learning around projects (Blumenfeld et al. 1991). This method typically involves finding solution of a real life problem that results in development of a final product and delivering some pre-defined project outcomes. Solutions are often constrained by pre-defined project requirements. To carry out projects, students work often in teams for a considerable length of time.

Problem-Based Learning is an approach in which a problem is presented to students first in order to stimulate their prior knowledge and to encourage them to learn new things in order to solve that problem (Barrows et al. 1980). Students work in teams and practice self-directed learning while teachers act as facilitators. The outcome and the way to find a solution are not pre-defined.

Research-Based Learning emerge from the idea of linking research and teaching, and engaging students in research and inquiry (Healey 2005). This approach helps students to think and act like a real specialists in their future professions (Healey 2005). Hodson in (Hodson 1992) summarizes research learning as learning about research, learning through research, and learning to do research.

Face-To-Face Teaching is a collective term for a variety of teaching methods and techniques. Lectures, tutorials and seminars with using traditional one-way transmission of content and techniques of small group teaching (the group size varies between two and 20 participants) are considered in T-CHAT.

To deliver a module using T-CHAT, knowledge and understanding of the aforementioned pedagogical approaches are required. To ensure student-centred learning and to address the development of skills and competencies, the learning module needs to be oriented on the intended learning outcomes (ILO), which are derived from the professional and social requirements to contain the coordinated design of learning activities and assessment tasks (see Constructive Alignment in (Biggs 2011)). A sequence of learning activities and assessment tasks defines a learning process. Thus, knowledge of the following attributes of a pedagogical approach is required:

- Learning activities as well as their possible combination within the learning process that may be provided by the pedagogical approach,
- Assessment tasks integrated in these learning activities and aligned to
- ILOs -what students need to be able to do by the end of the module - in terms of acquisition of knowledge as well as development and improvement of competencies.

This paper briefly discusses the PjBL pedagogical approach, on its above attributes, and on how it may be applied within the context of the T-CHAT teaching approach. To elaborate understanding about the above attributes of the PjBL approach, a qualitative literature review has been conducted. Books, journal publications and conference papers that form this understanding were identified and then analysed. Studies concerning the PjBL pedagogical approach in context of “Education” and “Engineering” and published to 2019 were searched on digital libraries (Web of Science, IEEEXplore, ACM Digital Library, Elsevier Science Direct, and SpringerLink). Numerous relevant studies were analysed based on the title followed by the abstract to exclude not relevant ones. The studies written by renowned authors of the field have been analysed first. Literature sources referenced there were also analysed. The literature can be divided into three parts: 1) theoretical work in the field of subject matter, 2) literature review, and 3) empirical studies and implementations for engineering education.

LITERATURE REVIEW: SUMMARY OF INITIAL FINDINGS

Projects in PjBL usually result in a solution of a problem or creation of a final product, e.g. a design or a model, and in delivering some pre-defined project outcomes, e.g. a product

presentation or a project report. However, in PjBL modules both the final product and the process are essential for students' successful learning, for enhancing students' practical and professional experiences and for acquiring an understanding of their future work. The following subsections outline learning activities, assessments, and learning outcomes in form of competencies that should be considered while delivering the PjBL approach.

- Learning Activities

In order to understand which learning activities (LAs) are utilized in the PjBL approach, knowledge about the corresponding learning process is required. In PjBL, students may be given different levels of autonomy to work and manage their projects: beginning with the pre-defined task to be solved and methods to be used, and ending with autonomous work on their own responsibility (De Graaff & Kolmos 2003). To support students in project management and to monitor students' progress, management frameworks for student projects in engineering education has been used (see (Lima et al. 2012), (Garcia Martın & Pérez Martínez 2017)). These frameworks are aligned to the project lifecycle and define project deliverables for each lifecycle phase. Table I lists which LAs may be offered to students during the course of a project.

TABLE I LEARNING ACTIVITIES

Learning activity	Description	References
Keeping a reflective journal	Continuous record of experiences, reflections, and problem-solving during a project	(Blumenfeld et al. 1991) (Barron & Darling-Hammond 2008) (Hosseinzadeh & Hesamzadeh 2012) (Arana-Arexolaleiba & Zubizarreta 2017)
Keeping a portfolio	Collection of students' work in the course of the project, their progress and personal reflection	(Barron & Darling-Hammond 2008)
Solution review	Presentation of work in progress to obtain feedback from peers and instructor	(Barron & Darling-Hammond 2008)
Team or whole class discussion	Discussion to provide new ideas and explanations	(Barron & Darling-Hammond 2008)
Performing regular reflections	Addressing concerns, difficulties and feedback of students about the PjBL process	(Fell 1999) (Barron & Darling-Hammond 2008), (Hosseinzadeh & Hesamzadeh 2012), (Lima et al. 2017), (Arana-Arexolaleiba & Zubizarreta 2017)
Continuous feedback	Through peers and instructors in oral form to the students, and reports' feedback, done as a detailed review of each team's report with comments/ corrections/ suggestions	(Barron & Darling-Hammond 2008), (Lima et al. 2012), (Lima et al. 2017)

- **Assessment Tasks**

For PjBL pedagogical approach both formative and summative assessments are applied. Accurately assessing students' collaborative work is difficult. Instructors mostly have a restricted view of group work in terms of contribution and participation of individual students, which often results in biased judgements (Gweon et al. 2017). Therefore methods, other than final individual exams, should be applied for assessment of collaborative work.

Formative assessments, if regularly performed, contribute on the one hand to the improvement of learning behaviour of students, and on the other hand give the instructor an opportunity to control the learning process (Blumenfeld et al. 1991) (Barron & Darling-Hammond 2008). They should be integrated into learning activities, be reflective, and be iterative within the module (Barron et al. 1998) (Helle et al. 2006) (English & Kitsantas 2013) (Hosseinzadeh & Hesamzadeh 2012) (Lima et al. 2017) (Johnson & Ulseth 2017). Self-assessment is part of the assessments implemented in empirical studies (see (English & Kitsantas 2013), (Hosseinzadeh & Hesamzadeh 2012), (Verbic et al. 2017), (Hall et al. 2012), (Shuman et al. 2005)).

Weekly reports with responses to a set of questions and performance assessments can be used for summative assessment (Barron & Darling-Hammond 2008). As summative assessments at the end of the project individual written and oral examination, project presentation, writing a report, and solution demonstration are conducted (Lima et al. 2017) (Johnson & Ulseth 2017) (Arana-Arexolaleiba & Zubizarreta 2017). To grade them a rubric (Popham 1997) is often used that specifies the judgement criteria (see (Verbic et al. 2017)). As students differently participate in team work and contribute to the project success and the final product, it is important to account for individual effort in assessing team performance. So the final team grade is individually adjusted according to the individual contribution of each team member based on self- and peer-assessments (Hall et al. 2012; Verbic et al. 2017; Lima et al. 2017).

- **Developed Competencies**

To investigate which competencies are developed by the PjBL pedagogical approach, a distinction is made between disciplinary competencies that encompass field-specific knowledge and skills in the subject, and key competencies (also named as generic competencies, generic

skills, or transferable skills in the literature). Key competencies are classified by (Orth 1999) in four categories 1) social competence (e.g. the ability to communicate and collaborate), 2) personal (e.g. responsibility, self-esteem, leadership), 3) systematic (e.g. problem-solving and analytical skills), and 4) general competence (e.g. project management).

A few of authors report of competences that are enhanced or developed by PjBL. While acquisition of content knowledge and its application to new problems and situations are mentioned in the majority of research papers, different key competences are reported by different authors (see Table 2).

TABLE 2 KEY COMPETENCIES DEVELOPED IN PjBL

COMPETENCE	REFERENCES
Social Competence	
Collaboration	(Mills & Treagust 2003), (Lima et al. 2012), (Bradley-Levine & Mosier 2014), (Kolmos 1996), (Johnson & Ulseth 2017), (Arana-Arexolaleiba & Zubizarreta 2017)
Communication	(Mills & Treagust 2003), (Hosseinzadeh & Hesamzadeh 2012), (Lima et al. 2012), (Arana-Arexolaleiba & Zubizarreta 2017)
Presentation	(Kolmos 1996), (Johnson & Ulseth 2017), (Arana-Arexolaleiba & Zubizarreta 2017)
Writing	(Johnson & Ulseth 2017), (Arana-Arexolaleiba & Zubizarreta 2017)
Personal Competence	
Self-directed learning	(Hosseinzadeh & Hesamzadeh 2012), (Johnson & Ulseth 2017), (Mills & Treagust 2003)
Ability for self-assessment and assessment of other	(Hosseinzadeh & Hesamzadeh 2012)
Leadership	(Arana-Arexolaleiba & Zubizarreta 2017), (Lima et al. 2017)
Systematic competence	
Critical thinking	(Bradley-Levine & Mosier 2014), (English & Kitsantas 2013)
Analytical skills	(English & Kitsantas 2013), (Kolmos 1996)
Problem-solving skills	(Arana-Arexolaleiba & Zubizarreta 2017), (Bradley-Levine & Mosier 2014), (Hosseinzadeh & Hesamzadeh 2012), (Kolmos 1996), (Mills & Treagust 2003)
General Competence	
Project management	(Kolmos 1996), (Helle et al. 2006), (Lima et al. 2012), (Johnson & Ulseth 2017)

DISCUSSION

Intended learning outcomes (ILO) specified in form of competencies are the starting point for how to use PjBL in a module delivered with T-CHAT. Based on these ILO, learning activities (LA) and assessments are selected aiming to developing those and integrated with the LA of other pedagogical approaches of T-CHAT to build a learning process. Acquiring disciplinary competencies (DC) are the main goal of learning in engineering education because they cannot be compensated through well-developed key competencies (Weinert 1998). To steer the

development of DC, in T-CHAT students are provided with a pre-defined task and with the autonomy and responsibility to work. The project task should be complex enough to motivate students to generate questions and ideas of their own (Helle et al. 2006) and be open enough so that students can apply different solutions and methods and take decisions with imprecise information (Lima et al. 2012). Table 3 presents an example of ILO of an engineering module and how these ILO can be addressed by LA and assessments.

TABLE 3 LEARNING ACTIVITIES AND ASSESSMENTS ADDRESSING MODULE LEARNING OUTCOMES

Intended learning outcomes (Competencies)	Learning activities and assessments
Disciplinary competencies	<ul style="list-style-type: none"> - Depending on the disciplinary competencies to be developed in the module, the instructor specifies a task that is often interdisciplinary. - Keeping a reflective journal. - Keeping a portfolio.
Key competencies	<ul style="list-style-type: none"> - Keeping a portfolio.
Collaboration	<ul style="list-style-type: none"> - Team work on a project task. - Regular reflections - addressing concerns, difficulties and feedback of students about the PjBL process.
Communication	<ul style="list-style-type: none"> - Team discussion. - Whole class discussion. - Regular reflections addressing concerns, difficulties and feedback of students about the PjBL process.
Presentation	<ul style="list-style-type: none"> - Project presentation as a summative assessment. - Solution review to obtain feedback from peers and instructor.
Technical writing	<ul style="list-style-type: none"> - Writing a project/final product report as a summative assessment.
Self-directed learning	<ul style="list-style-type: none"> - Students work autonomously. The instructor periodically controls the project status and assists in case of problems or gaps.
Ability for self-assessment and assessment of other	<ul style="list-style-type: none"> - Self- and peer-assessments for adjusting grade according to the individual contribution. - Rubric
Leadership	<ul style="list-style-type: none"> - Giving responsibility for the learning process and final results to the students.
Critical thinking	<ul style="list-style-type: none"> - Selection of a project task. - Solution review.
Analytical skills	<ul style="list-style-type: none"> - Selection of a project task. - Continuous feedback.
Problem-solving skills	<ul style="list-style-type: none"> - Selection of a project task.

A challenge of the wider study is the amount of literature, both theoretical and empirical.

CONCLUSIONS & RECOMMENDATIONS

This paper provides an introduction to the T-CHAT teaching approach, briefly focusing on the key attributes of the PjBL pedagogical. By combining PjBL with the other pedagogical approaches that form T-CHAT, it is anticipated that a greater learning benefit can be achieved.

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Building a Living Curriculum for STEAM: An International Perspective

Preston, Anne^a, Giglitto, Danilo^b, Lazem, Shaimaa^c, Price, Linda^d,
Elkington, Sam^e, Stone, Peter^f

University College London^a, Sheffield University^b,
City for Scientific Research & Technological Applications, Egypt^c,
University of Bedfordshire^d, Teeside University^e, Newcastle University^f

Corresponding Author's Email: anne.preston@ucl.ac.uk

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ABSTRACT

This paper contributes to developments in addressing the ongoing needs of engineering students in the area of human-centered and human-oriented technology innovation to promote debate on future-facing curriculum design in engineering education. We address these as part of the activities of The Hilali Network, a transnational collaboration which transcends geographic and conceptual borders to merge current reform in UK and Egyptian engineering education and local community-led digital preservation and protection of Intangible Cultural Heritage (ICH). One aim of the collaboration is to identify educational methodologies and principles for remixing the design of engineering higher education alongside traditionally underexplored areas in STEAM, in this case cultural heritage. In this paper, we report on the design, implementation and evaluation of our activity which aimed at developing a STEAM-based Living Curriculum, drawing on established and the latest Higher Education and Human Computer Interaction (HCI) approaches coming from both the UK and Egypt.

TACKLING INFRASTRUCTURES FOR PARTICIPATORY TECHNOLOGY DESIGN EDUCATION IN ICH AND ENGINEERING EDUCATION

One of the most important activities in our STEAM-based work was to facilitate, with students and local communities, an infrastructure for participatory technology design in the documentation of the Intangible Cultural Heritage (ICH) of several tribes of Bedouins living in North-Central Egypt. ICH is commonly known as ‘traditions or living expressions inherited from our ancestors and passed on to our descendants, such as oral traditions, performing arts, social practices, rituals, festive events, knowledge and practices concerning nature and the universe or the knowledge and skills to produce traditional crafts’ (UNESCO, 2003).

In doing so, we tried to overcome several barriers that might generally affect most attempts to engage ICH gate keepers and, by the same token engage computing science students, in digitally-mediated and heritage-oriented projects.

The Bedouins of North-Central Egypt are going through a transitional period. After having been nomadic for centuries, they have become settled communities with far-reaching consequences in terms of social structure and cultural practices. This community is well aware of the trade-off they are going through. Some traditions and customs related to a more traditional and nomadic lifestyle are disappearing as they embrace more urban and modern habits.

For instance, the skills necessary for desert life – such as their mastery of transportation by camels and trace tracking – are no longer practiced. Besides, having settle also means that other cultures (such as the Salafi’s and the wider Egyptian’s) have a stronger influence, which in manifesting in the length of marriage celebrations becoming shorter, improvising singing skills held by the women fading away, the culinary traditions linked to the use of a bonfire being abandoned, and other customs such as face tattooing and traditional clothing being replaced more modern dressing styles.

However, all these practices hold an unchanged cultural relevance for the community in defining and shaping Bedouin identity. In fact, the Bedouins look with nostalgia at what “being a Bedouin” meant compared to the fading defining culture of present days. For these reasons, many members of this community recognise the necessity of stepping up in taking care of their ICH.

In terms of Egyptian engineering education, we wanted to directly engage with Egypt's move to draw on the UK's HE models and current practices. Initiatives are growing to modernise heavily technically-oriented approaches to computing science education by sensitizing students to design thinking and contemporary HCI studies which encompass social and cultural studies (Lazem, 2016; Preston & Lazem, 2016). To this end, we are developing a sustainable approach through designing a living curriculum aimed at engineering students.

We adopt a definition for the living curriculum that “repositions learning as a continuous conversation within a dynamic curriculum that is integrated with, and takes advice from, the world our students live in” (Marshall and Wilson, 2012, p .2). This resonates well with the ethos of HCI education that values the users and their participation in design.

In living curricula development in HCI, there has been a specific focus on creating educational resources to address the needs of engineering students in the area of human-centered and human-oriented technology innovation. As Churchill, Bowser and Preece, (2016), make clear:

“they need to develop investigative, analytical, technical, communication, and advocacy skills to help them shape interactive technologies that augment people’s abilities, enhance their creativity, connect them to others, and protect their interests” (p. 70).

We propose that, in the Egyptian context, the development of the living curriculum is an opportunity for reimagining civic education by encouraging engineering students to engage with their communities on issues of public concern.

AIM AND OBJECTIVES

Our aim with this part of the cross-disciplinary project was to develop and apply principles and approaches for a STEAM-based Living Curriculum, with a focus on ICH and computing science education, drawing on links to established and the latest Higher Education and Human Computer Interaction approaches coming from the UK and Egypt.

With this in mind, our practice-based research question: *‘What should a living curriculum for ICH and computing science learning look like?’* drew on a set of working design principles: Co-creation, Sustainability, Localisation, Real-world application and Openness. We used these principles to

underpin the design, iterative development and evaluation of a summer school for computing science students in Egypt.

CONTEXT: THE 2017 HILALI SUMMER SCHOOL

The technology design activity took place within the 2017 Hilali Summer School held at the City of Scientific Research and Technological Application (SRTA-City) in August 2017. The school was designed to provide students with participatory experiences to technology design by adopting and adapting a well-known model from a combination of the Double Diamond model (*Design Council*, no date) and a user-centered design process (for example see Sharp, Rogers and Preece, 2007). Activities were based around Discover – Define – Develop – Deliver with every two phases forming a diamond shape. Activities in the first and third phases were exploratory whereas the second and fourth were for narrowing the scope (understanding users) and defining focus (feedback from community).

Activities within the phases of the diamond were stimulated by working design principles of the project. Each activity lent itself to a greater or lesser extent to these. For example,

Localisation: culturally relevant information to develop a curriculum, for example, using real-world case studies to develop the activities and for us subsequently, guidance for educators.

Co-creation: processes for creative (original and valuable) generation of shared meaning and development

Sustainability: manifested via artefacts, educational objects created by the teachers and students during the course of their learning experiences – something which is lasting, public and material (not deleted or hidden after completion)

Real-world application: inclusive artefacts, tools and educational processes from the local context for learning and for the application of that learning

Openness: curriculum development which is explicit about the methods used to create the tools and learning experiences and the promotion of re-use and re-mixing of curriculum design approaches and content

More information on the activities and students' experiences of the summer school can be found on The Hilali Toolkit.

EVALUATION OF STUDENT-DESIGNER PROJECTS

The Bedouins warmly welcomed our attempt to explore Bedouin ICH and our subsequent proposition to collaborate in the design of four mobile apps for ICH self-documentation.

Although this experience represented a unique opportunity for the Bedouins to explore a technological framework to document their heritage, many challenges were embedded in this attempt.

Despite their willingness to participate, the engagement practices had to be planned in a way that did not make the Bedouins feel challenged by the proposed tasks. This is because early fieldwork revealed a non-exploratory mind-set and the reluctance to partake in activities they did not fully understand. Besides these behavioural aspects, there were further challenges more specifically linked with ICH.

The Bedouins hold a great pride in their culture, and they are fastidious about any extent of mistake they may find in digital representations of heritage. This last trait was addressed by a great involvement of the Bedouins in the aesthetic features of the apps so to generate final prototypes to which they could identify more easily.

The mobile application design attempted to also respond to their concern that young family members know less about their heritage as they started going to schools and interacting with modern technologies. The resulting generational gap – which, in cultural terms, is common to many cultures across the world – in terms of who knows old Bedouin traditions and who has enough digital literacy to document them was bridged by the proposition of a prototype that could capture the interest of the youngest generations through a gaming approach.

Overall, all these challenges were overcome brilliantly by the student-designers. Along the road, we and they learned three main lessons that may contribute to the increasing an international approach of technology deployment for heritage purposes. Firstly, user-friendliness is not

enough to foster participation. The ethos of our approach was putting the benefits for the community before the tool. The benefits were identified by the community, who saw in designing the apps to counteract an atavistic misrepresentation that the members lamented.

Secondly, we soon realised that three further and interrelated factors we needed to promote in order to enact the participation of the Bedouins: motivation (by focusing on the motivations for them), ownership (by consistently including them in the decision-making process), and authenticity (by co-designing a framework in which to juxtapose the misrepresentation that they feel is occurring in mainstream heritage).

Thirdly, the entire project (including the mapping of heritage, the investigation, and the technology design) was localised, therefore, the potential cultural and linguistic barriers between designers and heritage keepers were limited.

RECOMMENDATIONS FOR PRACTICE: GUIDELINES FOR TECHNOLOGY DESIGN DIMENSIONS IN A LIVING CURRICULUM

In May 2018, we invited an interdisciplinary team of international UK based policy makers, heritage and engineering educators, students, practitioners and researchers to participate in our UK workshop called Building a Living Curriculum for Cultural Heritage and Science, Technology, Engineering, Arts and Maths. We not only further trialled some of the student-led activities used in the summer school with participants but also used student-led findings from it to stimulate discussion. In doing so, we wanted to advocate how educators and students could adapt their existing curricula and create new experiences to address the challenges of STEAM based learning, particularly from a living curricula perspective. Whilst not all these participants were from the engineering education field, our aim was to learn lessons and gain insights into the benefits engineering education could gain from in extending its curriculum focus from engineering-specific lens on STEAM to those which are more broadly informed by other disciplines. In order to do this, we sought to look ‘beyond engineering’ in the first instance.

Here, we share technology design dimensions revealed via participants at that workshop which we believe are the most significant as outcomes when using a living curricula approach in

engineering higher education programmes. In our case the focus is on ICH, but technology design dimensions could also form the basis of defining the other kinds of living topics to discuss to support STEAM education where students are encouraged to work with communities using a living curricula design:

Resilience: Durability (or lack thereof) of heritage platforms is a real issue. As funding is temporary by definition, many projects may suffer from dependency on injection of money. It is, therefore, crucial that a sustainable long-term strategy is developed altogether with the technology.

Accessibility: It is extremely important to be sensitive towards different level of digital literacy in order not to obtain fragmented contributions in a tool.

“challenges usually stem from accessing communities, identifying them and subsequently adapting the training to their needs and to the particular scope of each project” PhD Student, Sustainable Heritage.

Interpretation: As heritage is contested, a heritage digital project should try to bring within the digital environment the process of symbolic interpretation and meaning negotiation that happens between ICH keepers offline.

“Some aspects of cultural heritage will be better examined, or expressed manually/physically rather than digitally using different technologies. However, this doesn’t mean that the use of technology to support such projects is not beneficial” Postgraduate student, Education.

Application: This refers to the necessity of grounding the usefulness of the technology to address real-life heritage problems.

“If we provide a context to ‘intangible cultural heritage’, and we are not from that same culture, we may also be documenting our own values and perceptions, exposing the research to unconscious bias and changing something genuine” Senior Lecturer of Economics.

Customisation: As ICH may change over time (together with how it is interpreted by a community), a technology should be customisable in that it could be adapted to new forms of

contributions to also enhance its future-proof capabilities. The customisable aspects should also regard different age groups or group of interests.

“Technologies are being advanced rapidly rendering their sustainability and maintenance challenging”
Course director, Sustainable Heritage.

Infrastructure: The technology design and subsequent development of software should be in line with the hardware components and network capabilities of the potential group of users.

“The most genuine elements of cultural heritage can sometimes be located in places without proper internet connection and/or electricity” Senior Lecturer of Economics.

Transparency: The motivations of academics, researchers, students and designers affiliated with the project and technology proposition should be clearly stated to the heritage keepers involved.

“The main challenge to technologically mediated cultural heritage work includes: Cultural literacy, Empathy, toleration & respect, Transparency & openness, Accountability, Recognition and acknowledgment. As teachers, designers & citizens we will be creating technological resources celebrating diversity, multiculturalism and we must be prepared to defend them.” Senior lecturer in Creative & Cultural Industries.

Attitudes to technology: The perceived role of technology and attitudes towards it within a community should be carefully explored, possibly as one of the earliest stages of a digital heritage project.

“When trying to meet students’ needs in a heritage-technology project, there are challenges in addressing students’ attitudes or perception on the use of technology for learning e.g they lack the skills or fear of technology” Online learning facilitator.

CONCLUSIONS

The road towards extending the relevance and scope of STEAM-based education in the ways we have done here, is far from straightforward. Our findings and reflections thus far point towards potentially successful directions and the basis for a future research and educational design agenda, where the aforementioned guidelines for technology design dimensions in a living curriculum are carefully explored. Reflecting in detail and adapting the kinds of activities we undertook was made possible due to our successful research funding and importantly, the investment of both our students and partners in the process. This allowed us to design and evaluate our work in-depth and with a number of resources. However educators need not take this specific route if they are interested in experimenting with one or more approaches we describe here, especially if they already cover some of the areas of Discover – Define – Develop – Deliver in their existing programmes. Advice and information about building this kind of living curriculum can be found in our toolkit: www.hilali-toolkit.com.

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Encouraging Petroleum Engineering Students to Research the Environmental Implications of the Oil and Gas Industry

Salazar, Pablo

University of Portsmouth, FHEA

pablo.salazar@port.ac.uk.

KEY WORDS: Petroleum Engineering, Curriculum, Research, Unobtrusive, Environment

ABSTRACT

This paper summarizes the findings from a small-scale research project carried out in 2019 to better understand how much teachers, in Petroleum Engineering (PE), encourage students to research the environmental implications of upstream and downstream activities in the oil and gas industry.

This unobtrusive research follows a post-positivist rationale and combine quantitative and qualitative analysis to understand the reality as it is. Inductive content analysis was used to categorize 145 projects, advertised by 10 faculty members in a public data base, breaking the project's description into units that were counted and classified by using inductively defined keywords in a systematic approach that neutrally describe the facts.

Following the categorization, further quantitative and qualitative analysis allowed scoring and exploring the nature of the content and further reflexion incorporating the assessment of the PE (Petroleum Engineering) curriculum for the 2019/20 academic year.

Less than 10% of the overall portfolio of research projects on offer are related to environmental related topics or implications in the oil industry. Furthermore, lecturers seem to be anchored

to technical engineering subjects using complex terminology to describe their projects with very limited use of language related to the environment.

Although in the PE curriculum are three units addressing environmental issues associated to the energy sector, teachers and faculty member should do more to encourage students to develop knowledge and skills in this area, as part of their duty as professionals.

INTRODUCTION

Environmental concerns, safety and social responsibility are more relevant in the PE curriculum, therefore teachers must introduce these concepts and play a vital role helping the industry to raise environmental awareness among students at early stages of higher education by discussing operational activities and procedures, organising workshop and promoting research, aiming to better prepare students applying social responsibility values for environmental protection (Ershaghi & Paul, 2017).

At the same time, the curriculum needs to have up to date content and appropriate coverage to stimulate student's participation and allowing them to learn something useful and adhered to the trend of the job market (Zhao, Ma, & Qiao, 2017). Subtle communication skills, adaptability, social and environmental responsibility will matter most, and they will be the main skills to be learned to succeed (Petroni & Lynch, 2019).

This research follows an unobtrusive anonymous data gathering approach without any face to face contact extracting the data from a public data base available in the School of Energy and Electronics (SENE) that can be accessed by students and by faculty. This data base is regularly populated by 10 different teachers who are updating the portfolio of research options for students and contained a total of 145 projects in March 2019.

Quantitative textual analysis, carried out on the descriptors of the projects in the data base, allowed the inductive definition of categories within groups determined by the presence or absence of inductively defined keywords (McKee, 2003). Those keywords showed which

projects are somehow related with the research of environmental subjects associated to the oil and gas industry (Zamani, Vogel, Moore, & Lucas, n.d.).

Less than 10% of the projects on offer addressed environmental subjects and were classified as green projects. Results indicate that teachers are mainly interested on technical topics oriented to further develop their own specialised subject knowledge instead of alternative elements of the profession such as, contextual and cognitive knowledge or social and environmental responsibility.

Essentially 3 units in the PE curriculum are somehow addressing environmental concerns, sustainability and global environmental management in the energy industry and the final individual projects are the extra option for students to further develop their knowledge in this area.

LITERATURE REVIEW / RATIONALE

Petroleum Engineering is a great profession that is fun, intellectually and physically challenging, personally and financially rewarding and critical to global sustainability. Petroleum Engineers help people to live a better life, enabling transportation, keeping people warm and providing materials for good that are part of a modern lifestyle, ultimately they must deliver affordable energy from oil and gas without threatening our planet and future generations (Mody, 2019).

What is happening in PE education will have social, cultural, political and individual implications, therefore collecting and analysing data through educational research allows answering educational questions aiming to improve educational practice, better understand the world, improve policies and programmes and refine our theories.

The research process can be engaged in different ways, using primary or secondary data and carrying out the investigation either qualitatively, quantitatively or combining both. All research methods incorporate epistemological and ontological assumptions, which justify the philosophical positions of the researcher.

Regardless the inconsistencies in the terminology used by researchers in social science to differentiate between research methods and data collection methods from research methodology, it is understood that epistemology refers to what acceptable knowledge in a discipline is and the methods used to get that knowledge, while ontology refers to the nature of the phenomena under investigation and the assumptions on that nature (Siti, 2010).

Positivism and post-positivism place rational observations as the key to understand the social world, using the scientific method to investigate the observed phenomena, creating empirical knowledge by systematic observations and experimentation to create relations of cause and effect that uncover objective truth (Corry, Porter, & McKenna, 2019).

Post-positivism identifies causal relations deductively and adheres to the scientific value neutrality asserting the world as it is, regardless how we would like it to be. Uses quantitative analysis to test theory or hypothesis and gradually develops a predictive model of nature (Siti, 2010). The use of methods of natural science in social research generates empirical knowledge that follow logical structures of inferences which results can be tested against objective data. Content analysis, a quantitative form of textual analysis, is used to gather information about how other people see the world and to make an educated guess at some of the likely interpretations that might be in that text. Breaking down the text into units that can be counted and categorised within groups derived from the presence or absence of keywords. Specifically, inductive content analysis happens where the categories are derived inductively from the text being analysed (McKee, 2003).

RESEARCH OBJECTIVES

Society is changing and younger generations are in favour of cleaner and more environmentally friendly sources and uses of energy, therefore it makes sense having a more environmentally friendly education for future engineers in the energy sector (Salari & Ehlig-Economides, 2019). In particular, the oil and gas industry, have a poor reputation surrounded by many misconceptions about its environmental performance, therefore PE students need more knowledge on these matters in order to be able to act as ambassadors for the industry (Petroni & Lynch, 2019).

Learning and developing awareness on the environmental implications that upstream and downstream activities have, create a connection between subject knowledge and the emotional system and teachers have the power to influence the way students learn by using alternative and flexible approaches, promoting research, interacting and better communicating these issues (Petrone & Lynch, 2019). I do believe that we, as teachers, are not doing enough to stimulate and motivate PE students to research and learn about the environment and the effects that the energy sector has on it, which constitutes my ontological position in this investigation and fundamental hypothesis.

The objective of this research is to answer a very specific question, which is, to what extent teachers use research projects to stimulate Petroleum Engineering students to investigate and develop awareness on the environmental implications of upstream and downstream activities? Students are the priority of education and the participants of the curriculum, they need to learn theory and practical skills along with developing research capabilities, critical thinking, communication and cooperation, therefore the curriculum must be diversified and oriented to a sustainable development of students (Zhao et al., 2017).

METHODOLOGICAL APPROACH

This project was conducted following an unobtrusive data collection method by using a public data base that academics use in the SENE (School of Energy and Electronics) to advertise research projects that they offer to students for their final thesis or dissertation. These advertisements are personal to each lecturer and they certainly reflect and disclose their individual research interests and choices; allowing comparison between different practice styles but without any claims on whether those descriptions are accurate or truthful. Similarly, the 2019/2020 curriculum was accessed from the University's web portal and the corresponding units' descriptors from the Units Data Base available in the SENE.

Since this is an unobtrusive research, using existing documentation as a sole means of getting details of the projects offered by teachers and the curriculum is a limitation. These projects' proposals are written by different people, therefore the different ways the content is described create divergence. Furthermore, examining one subject in the curriculum can be misleading

because academic hours allocated to categories or subcategories are not available and the sole mention of the topic will be used to consider the subject is addressed (O'donoghue, Doody, & Cusack, 2010).

KEY FINDINGS

The level of details provided in the description of the projects varies greatly among teachers, having from comprehensive descriptions of the objectives, methodology and expected outcomes that use up to 598 words to very short brief proposals of 10 words in one sentence, with most projects poorly described in less than 200 words. Tearing the content of those descriptions I identified 232 keywords that I used to categorize those projects based on their main subject area.

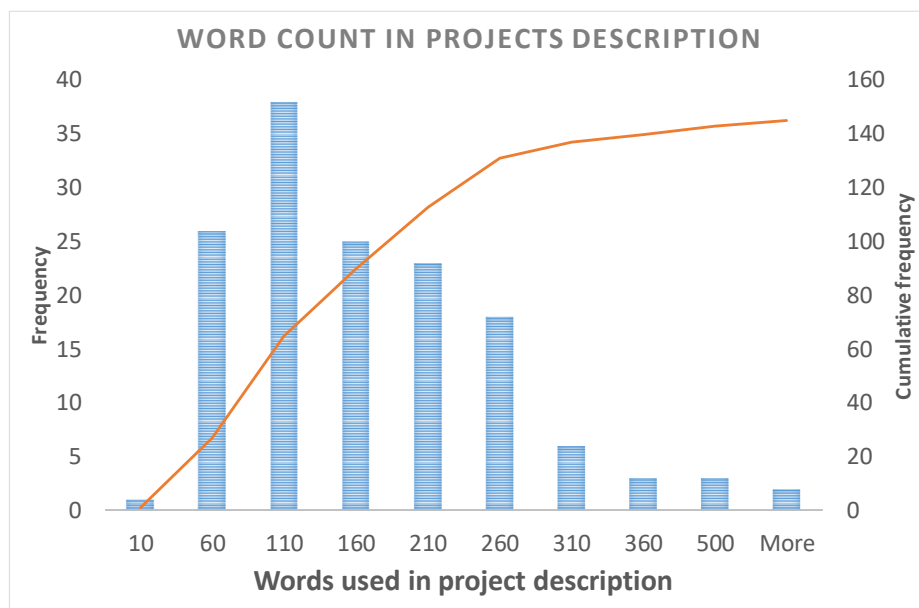


Figure 3 Statistical distribution of words count used in projects' description

Projects were grouped in 16 different categories based on the topics and subjects addressed, with most of them linked to petroleum engineering subjects, and only 5 projects classified in an environmental category.

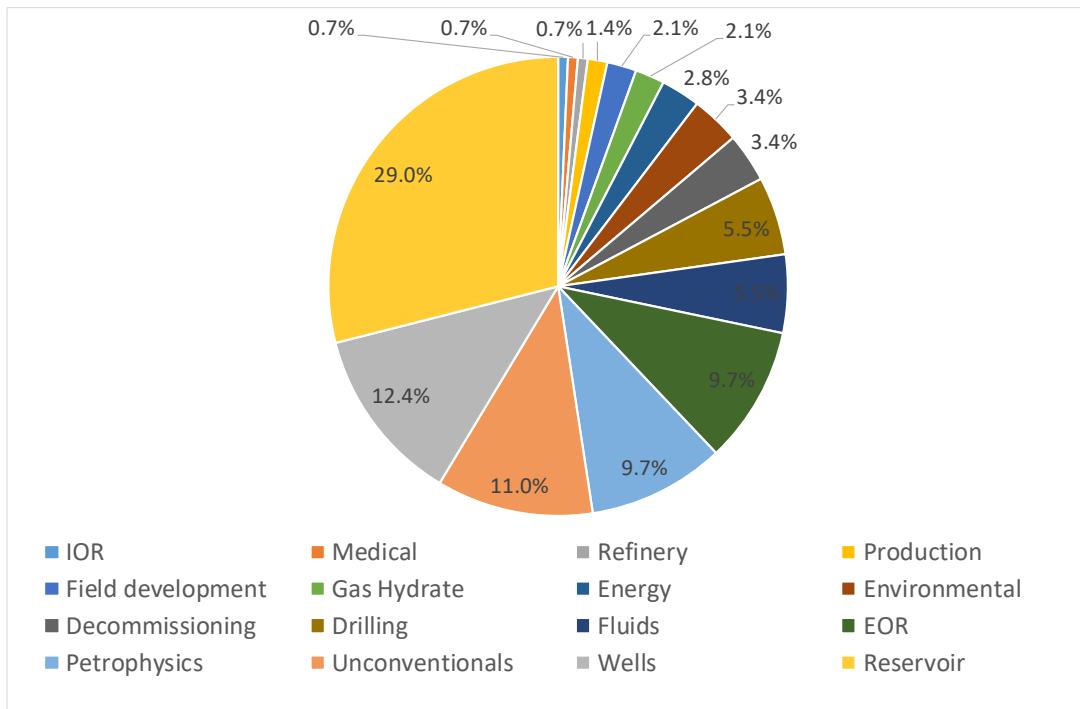
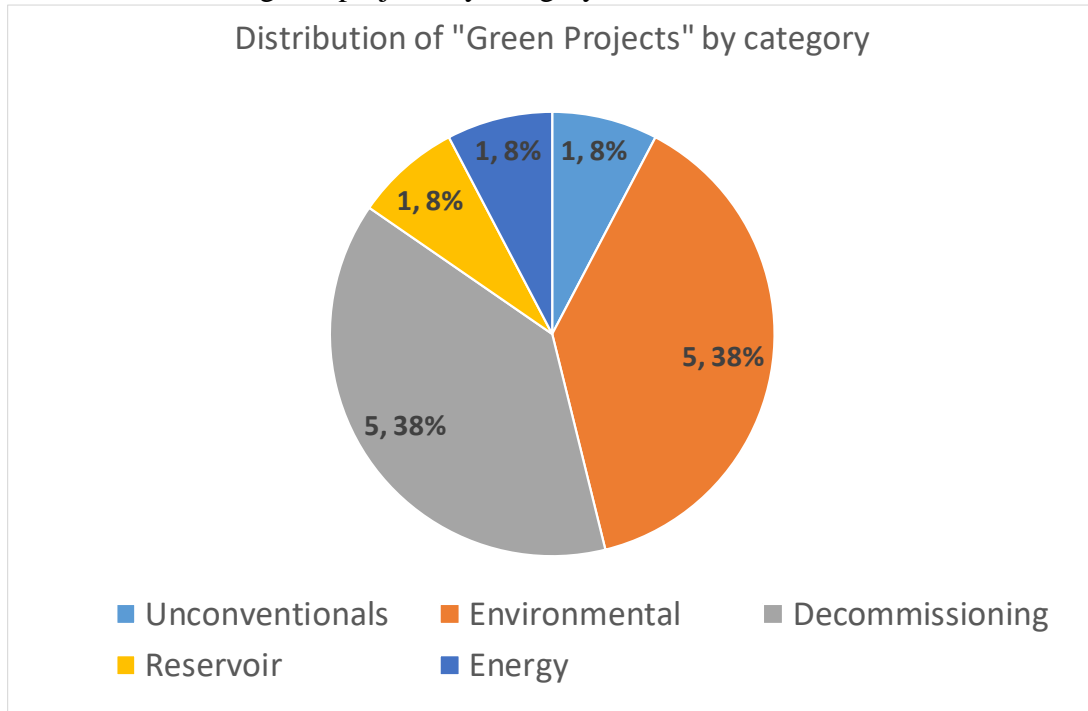


Figure 4 Projects distribution by category

From the portfolio of projects available in the data base a total of 13 projects (less than 10%) somehow address environmentally related matters, and those projects, named green projects, were classified in five different categories based on their main research topic. These green projects were characterized using specific keywords extracted from the descriptors, which are named green keywords. Those green keywords, 69 in total, represent one third of the total number of keywords that were inductively identified.

Figure 5 Distribution of green projects by category



The 2019/2020 curriculum for the undergraduate PE degree comprises 16 core units, distributed in 3 years, plus 1 optional unit in year 2. In addition to that, students pursuing master's degree level, have 6 additional units in year 4. After analysing the descriptors of all the units in the curriculum, using some of the keywords already defined while analysing the projects descriptions, I found that 3 units in the curriculum include environmental subjects in their syllabus and each of these units addressing specific issues. Unit ENG490 (year 1) is more focus on environmental implications and regulations related to upstream activities in the oil and gas industry, including their relationship to society, unit ENG593 (year 2) addresses the environmental concerns and sustainability in the downstream sector of the oil business and unit ENG608 (year 3) have a wider reach on global environmental management in the energy industry as a whole, in the context of sustainable development and optimum use of energy. Ultimately, unit ENG600, which is the individual research project in year 3, is another one where students can develop knowledge by researching environmental matters, however, that opportunity will depend on availability of projects in this specific area of knowledge, which was discussed previously.

DISCUSSION

As seen in

Figure 3, most projects lack of details in the data base, which can be misleading for students to understand the objectives and expected outcomes on completion of the project and can also confuse them when making choices on their preferred research topic. When looking at the terminology used to describe the projects it becomes clear that teachers are using a highly technical jargon to explain the investigation however not much use of language to encourage concerns for environmental aspects of the profession.

Although only 5 projects were classified in the environmental category, as shown in Figure 4, a total of 13 projects somehow promote research and develop awareness on the environmental implications the upstream and downstream activities have, and those projects were named green projects. These green projects represent less than 10% of the portfolio of projects available for students which is the consequence of having a minority of teachers incorporating environmental subjects in their proposals and prioritising their own preferred areas of knowledge, perhaps less controversial, or areas they feel more comfortable working with. Furthermore, the number of options offered by each teacher varies randomly, therefore some of them overloaded with projects supervision which might compromise the quality of support and time available for helping students throughout the development of their investigation.

The assessment of the curriculum was about understanding the effectiveness of the curriculum, identifying advantages and disadvantages and finding to what extent is addressing this specific area of knowledge related to the environmental management in the oil and gas industry. In this project the assessment was oriented to static content, including the evaluation, curriculum plan, curricular materials and learning outcomes.

CONCLUSIONS & RECOMMENDATIONS

The offer for green projects is limited and only few teachers are designing and proposing research activities to stimulate PE students to investigate the environmental implications that upstream and downstream activities in the oil and gas industry have. Instead, most lecturers are

favouring research on technical petroleum related subjects aligned with their personal preferences, which is also constraining the spectrum of research topics for students to choose from. Furthermore, the use of language when describing these projects is highly technical and complex with limited use of words that can trigger curiosity in subjects related with environmental matters in the oil and gas sector.

The level of details provided to students in the descriptors varies considerably among teachers, which can be influencing students' choices and even misleading the expected outcome of those projects. On the other side, clearly some teachers are more proactive in the number of projects they have on offer which can lead to an unbalance workload regarding supervision duties, which can also have an impact on students' performance and satisfaction.

The 2019/2020 curriculum for the undergraduate PE program has 3 units, one on each year, addressing topics related to the environment and the connections with the energy industry, therefore, to some extent, students can develop knowledge, skills and social responsibility throughout their studies. However, these learnings from the syllabus can be further reinforced and complemented with more options to carry out research on this area making their higher education more environmentally friendly.

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Partnering with Industry: Practical Considerations from Two Programmes

Gillen, Andrew^{ab} Ford, James^a Grohs, Jacob^b

University College London^a; Department of Engineering Education, Virginia Tech^b

Andrew.gillen@ucl.ac.uk

KEY WORDS: Industry Partnership, Outreach, Capstone Design

SUMMARY

Reflecting on both research and anecdotal evidence from two different engineering education programmes, we have developed practical implications for engaging with industry to support learning. While through our collective experience we have determined many positive reasons to consider partnering with industry, we also present areas of caution to consider when engaging with external partners for a learning experience. The two initiatives discussed in this paper are a school outreach programme that partners a university, industry, and school systems in the United States (Programme A) and a capstone integrated civil engineering design project that partners a university and nearby engineering firms in the United Kingdom. Despite the disparate nature of these programmes, we found points of comparison in consideration of the industry partnership aspect that they share.

BACKGROUND

There is a growing body of support for industry partnership to improve learning experiences in engineering. Outcomes from collaborations with industry in engineering education have been studied in a variety of contexts including school/community engagement (e.g., Buxner et al., 2014; Googins & Rochlin, 2000; Pawloski, Standridge, & Plotkowski, 2011) as well as undergraduate courses (e.g., Shin, Lee, Ahn, & Jung, 2013). Stakeholders in partnerships between industry and educational institutions must be sensitive to unique factors such as

supervisor perceptions of time spent away from work (Rogers & Cejka, 2006) and connections and conflicts between social and business goals (Stadtler, 2011). Through our two programmes, we have seen firsthand these and other considerations in practice.

PROGRAMME DESCRIPTIONS

Programme A: Programme A is three-year National Science Foundation funded project titled Virginia Tech Partnering with Educators and Engineers in Rural Schools (VT PEERS). It was awarded through the Innovative Technology Experiences for Students and Teachers program and brings together the University, three school divisions, and three local engineering industry partners. The project has two major goals:

- (1) Increase Youth Awareness of, Interest in, and Readiness for Diverse Engineering Related Careers and Educational Pathways.
- (2) Build Capacity for Schools to Sustainably Integrate Engineering Skills and Knowledge of Diverse Engineering-Related Careers and Educational Pathways.

Middle school teachers and industry participate in one classroom intervention per month and a summer summit event with the goal of integrating engineering into the regular science curriculum. Lesson designs were iteratively improved using guidelines adapted from Cunningham and Lachapelle (2014).

Programme B: Programme B is a civil engineering integrated design project for 4th year Masters of Engineering students and Masters of Science students. In the current structure of the project, students work together to develop a solution to a major civil infrastructure problem over two terms. Although they work in teams, they individually focus on a subdiscipline of civil engineering and lead a particular aspect of the project. Similar to other capstone projects (Pembridge & Paretto, 2019), teaching focuses on developing students' professional and technical skills in design including communicating with broad audiences, applying engineering knowledge, and exercising engineering judgement.

EVALUATING CRITERIA FOR THE PROGRAMMES

Programme A: VT PEERS has been the focus of several recent publications (Gillen et al., 2019; Grohs et al., In Press). Additional evidence that has informed some of the implications in this practice paper comes from the analysis of 76 semi-structured interviews with participants over the first year of the programme (i.e., teachers, teacher-leaders, university personnel, and industry participants) (Gillen, Grohs, Matusovich, & Kirk, Under Review). We used the seminal work in interorganisational collaboration from Gray (1989) and the framework from Thomson, Perry, & Miller (2007) to guide our analysis of the collaborative processes involved in the first year of partnership.

Programme B: Informally, the civil engineering integrated design project has been evaluated and adjusted over time by teaching-focused staff at the University. For example, newer project briefs highlight social issues and their connection to engineering problems. Research is currently a work in progress, but we plan to focus on both the organisational aspects as well as student learning. The frameworks that will guide this research effort are still under consideration. The implications described below for the project are informed by instructor reflections as co-coordinator of the programme for many years.

WHY PARTNER: INSIGHTS FROM OUR PROGRAMMES

Reflecting on our research and experiences, we have developed three main ideas around how partnering with industry is beneficial for university departments. Firstly, partnering with industry may help with professional development goals such as allowing youth to see a variety of engineering-related career pathways or build professional skills and experience in undergraduate students. Secondly, partnering with industry has the potential to add authenticity and realism to coursework. Lastly, we found hidden fringe benefits to working with industry in both programmes.

- **Partner for Workforce Development Goals**

Both programmes allow for interaction with staff from a wide range of professional engineering companies and disciplines. For outreach with youth, this means that students are able to interact with people who arrived at engineering from a variety of pathways, not just traditional undergraduate programmes. For students in the integrated design course, partnership is an opportunity to gain awareness of a range of professional practice approaches. The way that engineers from differing organisations and disciplines approach a problem will vary and students found it useful to witness this range towards developing professional judgement.

While youth in VT PEERS see industry monthly, students in the integrated design project benefit from meeting with their industry mentors on a weekly basis, often at the mentor's place of work. This gives students exposure to a professional work environment which better prepares them for life after university. This experience can also help hone their self-awareness of what sort of work environment or career path they may want to pursue.

Bringing outside expertise, whether into the middle school classroom or university course, also provides information for students on contemporary issues in engineering. Coupled with the academic coursework, this arms future graduates with a wider perspective and a more diverse awareness of the issues, approaches, and opportunities facing industry.

- **Partner for Added Authenticity**

Bringing engineers into the classroom is not just an opportunity to provide a role model but is also a chance to provide a more authentic learning experience. Adding authenticity and a sense that the classroom situation is akin to the real-world situation is beneficial for student motivation (Ambrose, Bridges, DiPietro, Lovett, & Norman, 2010). In the VT PEERS outreach activities, students heard testimonials from engineers about how their classroom lesson mirrored their professional work. In the integrated design project, the briefs have been designed with industry professionals and are often based on real projects. For example, one brief this year is focused on social housing design on a brownfield site.

- **Partner for Fringe Benefits**

Partnering with industry is an opportunity to network for undergraduate students. Many of our graduates go on from the integrated design project to work for their mentor's organisations and apply for jobs or work experience with some of our other industry partners. The industry staff involved also interact with other students not in the course when they visit the department and this has led to opportunities such as lunchtime seminars which are open to civil engineering staff and students from all years of study. In the VT PEERS outreach project, some industry partners and teachers have begun to work together on side projects, separate from university influence.

IMPLICATIONS FOR COLLABORATIVE PRACTICE

Although we have highlighted several benefits to partnering with industry, there are also significant challenges to consider with implications for collaborative practice. These challenges are twofold: issues pertaining to different organisational cultures and approaches and challenges establishing mechanisms for monitoring and feedback.

- **Culture clash: Aligning Industry and Instructional Approaches**

In our experience, when engaging with an industry partner it becomes important to have extensive discussions before a commitment is made to ensure that the approaches and views of both partners are broadly aligned. It is also important to be open about general philosophies and ethos towards engineering education to ensure that the aims of the partnership are not in conflict. In an undergraduate setting in particular, questions to discuss might include:

- Where do we see the future of the industry?
- What do we want our future graduates to be able to do?
- What do we see as the pressing issues of the day?
- What do we view as effective pedagogy?

A healthy diversity of views on all of these issues is appropriate, after all there is little point in collaborating with someone who will deliver exactly the same content that you would.

However, clashing views may result in an inefficient amount of time trying to reach a consensus, rather than focussing on design and delivery of effective educational content.

For outreach, some school participants worried about the way that industry would act in the school environment. Industry also felt uncertain about what to expect from their partners and the experience (Gillen, Grohs, Matusovich, & Kirk, Under Review). University-mediated training for those new to an educational environment, might help alleviate some of these issues.

- **Learning to Improve: Establishing Methods for Monitoring and Feedback**

Although it is challenging enough to have tough conversations around organisational values at the start of a project, it is perhaps even more challenging to turn this into an ongoing discussion. In both projects, the way that feedback has been shared and processed has occasionally fallen short of expectations. For example, in VT PEERS, it was unclear how to share critical commentary on partner behaviour in the classroom (Gillen, Grohs, Matusovich, & Kirk, Under Review). Similarly, in the integrated design project, there is often only an opportunity to share formal feedback from students at the end of the year. Using reflective questions like those found in Grohs et al. (In Press) may help catch issues before they become toxic to partnership success. For example, reflective questions may include: how partnering impacts day-to-day operations, how I see my and my partner's role, what is a comfortable balance of costs and benefits, and are the benefits too long-term for the short-term sacrifice?

CONCLUSIONS AND FUTURE WORK

When partnering to improve in an educational system, care needs to be taken to avoid common pitfalls and emphasise benefits. The focus of this paper was practical, but we hope to expand our research efforts as well. Specifically, we are currently developing a research plan to build understanding of how best to partner with industry in capstone design. We hope that by letting our professional experiences inspire our research questions, we will come to conclusions with not only scholarly significance but local impact on our instructional practices.

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Are Our Teaching Approaches Suited to the Current Generation of Engineering Students?

Davies, John W.

Hodgkinson, Liz

University of Plymouth

john.davies@plymouth.ac.uk

KEY WORDS: Engineering Students; Current Generation; Learning Preferences

ABSTRACT

Engineering lecturers often find fault with students' basic engineering skills yet are concerned about providing courses that appeal to 'generation Z'. In this study we asked students of civil engineering at the University of Plymouth, via group interviews, to identify matches and mismatches between the teaching on the course and their learning preferences, in order to determine whether the teaching approaches are suited to the current generation. Complete openness of access to all course material was identified as being at the core of their learning preferences. This includes course material and lecture content, accessed from the VLE as needed, and video capture. But students were clear that they enjoyed engaging in class activities, and identified working with examples in class, especially real-world examples, as a favoured method of learning. In effect, the students are seeking for their lecturers to control the class *experience*, but not to control, or to limit in any way, access to the *content* of the course. Most students had appreciation of the importance of basic engineering skills like sketching and hand calculations, but this came from industrial experience and not necessarily from their natural preferences or from course content.

INTRODUCTION

We were motivated to carry out this study while attending a staff away day for the School of Engineering at the University of Plymouth in July 2018. At one point in the day there was discussion of aspects that impacted negatively on students' performance on the courses (primarily civil engineering and mechanical engineering). The comments were predictable, some obviously important and some rather dreary, including: 'poor note-taking skills', 'poor attention span', 'poor skills in the use of sketching to present ideas', 'poor use of log books'. Certainly some of these comments seemed ironic in the light of a later discussion, which was about 'how do we ensure our teaching is connecting with generation Z'. We decided then and there to ask our students directly what they felt about the match or mismatch between the staff's teaching approaches and their own learning preferences.

SUMMARY LITERATURE REVIEW

Many published papers speculate on the characteristics and educational preferences of generation Z. One that is specific to engineering is by Moore et al. (2017), from the USA, which presents an extensive analysis of the differences between generations, and a discussion of developments in engineering education. They propose particular approaches that they feel will suit generation Z, including problem-based learning and a focus on information skills. A study by Barreiro and Bozutti (2017), in Brazil, directly considers the 'challenges and difficulties to teaching engineering to generation Z'. The study, based on a survey of teachers' perceptions and knowledge, identified 'a major problem ... in linking theory with practice', revealing at least as much about the emphasis within course delivery as about the learning preferences of the students. Boles et al. (2009), in Australia, consider 'synergies between learning and teaching in engineering'. They make the point that 'the interaction between the students' learning styles, lecturers' learning styles, teaching styles and philosophies ... holds a great potential for enhancing students' learning environments and outcomes'. The paper places emphasis on classification of learning styles, and a systematic matching between staff and students. Also in Australia, Grysbers et al. (2011) ask a question relevant to the current study, 'why do students still bother coming to lectures, when everything is available online?' They found that the great majority of science

students surveyed valued the experience of lecture attendance even when there was full online availability.

AIM / RESEARCH QUESTION

The aim of this small-scale case study involving civil engineering students at the University of Plymouth was to ask the question, ‘are our teaching approaches suited to the current generation of engineering students?’ The main reason was to determine whether changes should be made to course delivery of the course or to the assumptions of lecturing staff.

We didn’t want to start with assumptions based on other people’s characterisation of ‘generation Z’, not least because there was no reason to assume that engineering students, and specifically civil engineering students at Plymouth, would comply with any stereotype. We just wanted to ask the question.

METHODOLOGICAL APPROACH

This survey consisted of six semi-structured group interviews held with a total of 35 year 3 students of Civil Engineering at the University of Plymouth (24 male, 11 female; from two cohorts: 2018/19 and 2019/20), as shown on Table 1. Most had placement experience. The group interviews were facilitated by the two authors, both of whom had experience of running similar groups with students.

Group	Date	Number	Male	Female	With placement experience
1	5 March 2019	3	2	1	3
2	5 March 2019	4	2	2	4
3	25 March 2019	7	5	2	5
4	25 March 2019	4	4	0	2
5	15 October 2019	10	6	4	8
6	15 October 2019	7	5	2	3
Total		35	24 (69%)	11 (31%)	25 (71%)

Table 1 Interview group details

After completion of consent forms and confirmation about anonymity, the following statement was made.

'This is not a course feedback meeting. It is not about who's a good teacher or a bad teacher. However if there are specific examples of 'good' or 'bad' approaches that help you make a point, please use them. This is definitely not about who might be a good student or a bad student.

'Teaching in higher education typically takes place across a gap of a generation. Students today almost certainly want to learn in ways that are different from how their lecturers wanted to, or were forced to, learn when they were students.

*'There's actually just one question we want to ask you. **We're looking at the match or mismatch between our teaching approaches and your learning preferences. In that context, what do you like, and what do you not like, about civil engineering course delivery at Plymouth?***

The main question was deliberately open. Prompts were used to direct the students' focus to different aspects of the course.

The responses that relate directly to the aim are reported here. Other issues that emerged in the discussion about the course more generally have been reported back to the staff group.

KEY FINDINGS

One of the first points always raised was a preference for learning from worked examples, especially real-life examples, and for solving examples in class.

I think most people ... learn best when you're hands-on, so with worked examples we're doing it ourselves.

If I look at the lecturers or the modules that get the best attendance, that I enjoy the most, the ones that I do best at, are the ones where lecturers go through and do worked examples, because you can see how you'd use it in real life as well ... I'd follow that same process so I can see how I'd use it, in a job.

The other key preference was for teaching that is supported by open and comprehensive access to all material and lecture content. This includes course material, lecture presentation content, video capture and annotated notes.

In spite of the benefits of complete openness of access to material, students also seek to benefit from attending and engaging in classes.

The digital content and the lectures have to work hand in hand – each has to add something.

I think a mixture of the two is probably the ideal place to be because they complement each other ... [with] the Open University, you can sit at home and do it all yourself, but that's not what we signed up for here.

Reasons for attending include giving their studies a framework and discipline, the learning 'atmosphere' of a class, and the opportunity to collaborate with fellow students.

Did complete access to material make students less inclined to attend classes? The consensus was that it did not reduce their attendance, and that access to the material was most effective when supporting the experience in class.

If you're not going to attend, you're not going to attend, whether the material is there [on the VLE] or not.

In some discussions, a style of teaching which was effective in many ways but which did not include complete openness of access to all content (as a teaching strategy) was identified as 'old school'. This limit to access to course material outside the class did not suit the learning preferences of many students, and some found it frustrating.

What about 'traditional' engineering skills: for example, good sketching skills v. a preference for using CAD, or the use of hand, 'back of envelope', calcs v. using a spreadsheet? From discussion of these aspects it emerged that the students generally understood the usefulness of sketching and hand calcs, but this awareness had come from their industrial experience. They conceded that their own preference might otherwise have been for computer-based approaches, and it was clear that it was their industrial experience, not even their experience of the course itself, that had changed their attitudes.

I think everyone likes to think that they're going to using CAD a lot more and won't have to be doing sketching or hand calcs, that's why everyone is attracted to CAD and Excel ... In reality the moment you stand on a site and you're soaking wet covered in mud, you've got to draw it by hand because you're not going to have access to a laptop, and even if you did it wouldn't work because it's pouring down with rain.

People on site wouldn't look at CAD ... why are you giving me that, just sketch it for me? I think it's us not wanting to believe that we have to do it, we all think it's just technology technology.

They did indicate that their experience on the course had persuaded them of the importance of simplified calculations in one context: to validate output from software. And they appreciated the importance of developing the knowledge needed to understand that output.

Yes we know it's going to go into software but it's the fundamental knowledge behind it that makes you an engineer.

However, they made the convincing point that since much of the course put a focus on detailed analysis, the importance of simplified calculations was hardly likely to have prominence.

DISCUSSION

We realise that we were talking to the more engaged of our students. Participants were invited by email. The only incentives we were able to offer were coffee/tea and biscuits. Those attending were approximately one third of those invited. The other important (and related) characteristic is that most had been on placement, and this experience seemed to genuinely affect their attitudes to their experience at university.

In seeking to identify the match or mismatch between teaching approaches and learning preferences, our groups involved a deliberately wide-ranging discussion of what our students liked, and did not like, about their course. Emphasis has been given in this paper to aspects that point specifically to teaching approaches that are suited (or not suited) to the current generation of engineering students.

Two main favoured characteristics were identified. One was significant use of examples: worked examples, examples solved by students in class, especially where there was obvious real-world application. The other was complete openness of access to all material, including lecture content, video capture and annotated notes.

This desire for access to material does not equate to a 'take it or leave it' attitude to class attendance. The students wanted to engage in class activities; they would not have been satisfied just working with the material independently.

Industry experience greatly affects students' perceptions. In judging the value of good sketching skills (as opposed to always favouring CAD) or the use of hand calcs (as opposed to using Excel), experience of industry has persuaded the students to go against what might have been their natural preferences. Another impact of industry experience is that it enhances students' frustration when there is not open and comprehensive access to material and lecture content. Their experience of industry reinforces this.

*When I was on placement, if I missed something or I didn't hear something,
I'd ask again or I could always look it up again.*

This is part of an interesting tension between the learning preferences of the current generation of engineering students and the effect of any experience they have had of working in industry. In the case of sketching or the use of hand calcs, experience of industry has convinced the students that 'old-fashioned skills' have value in spite of their generation's supposed preference for computers. Whereas in cases where 'old-fashioned teaching' limits open access to material, what might be seen as their generational dissatisfaction with not being able to access all the material themselves is reinforced by their experience in industry.

CONCLUSIONS & RECOMMENDATIONS

Our overall interpretation is that the current generation of engineering students are seeking for their lecturers to control the class *experience* (for example, effective use of examples, engagement in class activities), but not for them to control, or to limit in any way, access to the *content* of the course. While the current generation want complete openness of access to course material, that doesn't mean that the importance of effective teaching in the classroom is lessened.

This small-scale case study has particular relevance to the delivery of civil engineering courses at Plymouth, but we hope that the findings are of interest more widely, to guide practice and course development and as an endorsement for industrial placements.

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Interdisciplinary Project Work to Learn and Integrate Contents in an Industrial Engineering and Management Programme - First Findings

Soares, Filomena, Alves, Anabela Carvalho
University of Minho, 4800-058 Guimarães, Portugal

fsoares@dei.uminho.pt.

KEY WORDS: Teaching / Learning Experience; Students' Perceptions; Production Systems and Automation

ABSTRACT

Often students have difficulties in relating learning content from different topics in a problem solving challenge. In order to tackle this issue the authors conducted a first experiment in the University of Minho. Organization of Production Systems and Process Control and Automation are course units taught in the 3rd year of the Integrated Master of Industrial Engineering and Management. Although with different content they have a common point: both refer to designing production systems and/or designing industrial applications to be integrated in the production systems, reducing waste and production time. The goal of the study was to challenge students to develop project work where they design a virtual or real-world automated production line. They simulated production cells to yield manufactured goods through a previously defined operating mode, including automated production subsystem components such as transport and supply chains. Students worked in groups with seven to ten members in each and the evaluation process included a public presentation, with the real-time presentation of the production line simulation, and work documentation, namely, video, Powerpoint presentation, simulations, poster, web page, and/or traditional word/pdf report. The preliminary outcomes from students feedback were positive which allowed the authors to conclude that this type of challenge is worth investing in for future courses.

INTRODUCTION

For a long time engineering education faculty members have been challenged by reports that suggest a need to improve teaching/learning methodologies to better prepare graduates for the workforce. Some of such reports come from professional associations and societies (ASCE, 2009; ASME, 2012; Graham, 2012), from companies (Manyika *et al.*, 2012; McKinsey Global Institute, 2019) and UNESCO (UNESCO, 2010) among others (Froyd, Layne and Watson, 2006; King, 2012). These reports are unanimous in stating that current graduates and early engineers lack competencies and knowledge needed for engineering practice.

Also, these reports point to a need for better collaboration between higher education and the workplace in the preparation and induction of engineering graduates. To achieve this, students would benefit from learning experiences that develop desired talents in the work environment, learning methodologies and activities that promote their critical thinking, stimulate their creativity and develop their collaborative skills. Such methodologies include hands-on activities, problem and project-based learning, among others.

Given that the global demand for engineers is rising, faculty are challenged to respond. Even if the heavy bureaucratic infrastructures bring difficulties in providing a timely and relevant response to change, a single effort from one or two teachers is better than none. This motivated two teachers from different knowledge fields lecturing in the Industrial Engineering and Management (IEM) programme to collaborate and assign a joint task to the 3rd year students. This task implies that the students, in groups, select, design and simulate an automated assembly line in a real-world or hypothetical company. They were free to decide and select the course unit contents to use and the form of the presentation of their work but they must include a hands-on of the simulated assembly line processing the product.

LITERATURE REVIEW

The UNESCO (2015) report “Rethinking education” states that learning to learn was never as important as it is today due to the volume of information now available on the internet. This demands competencies, considered as a broader concept than skills (Rychen and Salganik, 2001).

Nevertheless, competencies are difficult to achieve in purely passive education environments, i.e., the student being just a receiver of recipes given by teachers. Competencies are acquired in formal context, as well in informal, through activities promoted by the teacher but also by their peers in a network of collaboration where the individual performance is important. But, the team performance is also important (Zhang et al., 2008). The learning should take place, independently, of the space, time and relations in a fluid approach (UNESCO, 2015).

Implicit in this is an active environment where active methodologies, according to Bonwell and Eison (1991) should be promoted inside and outside the classroom. Active learning methodologies includes problem or project based learning (PBL), serious games, hands-on activities, role playing, among many others (Felder and Brent, 2006).

Promoting these approaches implies more motivated instructors who are willing to stop controlling the classroom, willing to leave their comfort zone and to be available to coach and guide the student to learn (UNESCO, 2015). At the same time, it is important for Higher Education Institutions (HEI) to have digital technologies to support classes (High Level Group on the Modernisation of Higher Education, 2013) and basic infrastructures such as teamwork rooms, i.e. flexible rooms with a capacity to change for different types of classes.

OBJECTIVE AND METHODOLOGICAL APPROACH

The goal of this study was to challenge third year students from the Integrated Master of Industrial Engineering and Management to design and implement a virtual or real-world based automated assembly line. To design this, they should apply the theoretical and practical concepts taught in two different course units, Organization of Production Systems I (OPSI) and Process

Control and Automation (PCA). Students organize their learning by consulting books, notes, guidelines and Powerpoint presentations provided by the teachers and class notes.

The outcomes of the first implementation of this study were analysed taking into account three issues: through observations, the qualitative feedback given by students and the analysis of the technical issues accomplished in the production line implemented.

THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

The content taught in OPSI and PCA (first semester of the third year) have a common point: they are devoted to production systems and industrial applications. Being aware of the difficulties students usually have in applying the concepts taught in different course units to a single problem and exploring active learning methodologies, the teachers of these two units challenged students to design a hands-on industrial-like assembly line. The proposed task was performed in groups of 7 to 10 members each. The work could be done a) in a company selected by the group or b) in a “virtual” company defined by the group.

Each team should approach an operating mode as for example Baton Touch; Rabbit Chase; Working Balance in Cell; Toyota Sewing System; Bucket Brigades in cell or in line (Alves and Hattum-janssen, 2011; Alves, 2018). They should design the assembly line/cell by estimating the demand for the product, defining the operations and calculating all the necessary elements (number of machines/operators/stations), balancing, defining the best deployment according to the chosen mode, the supply mode. They should also calculate performance measures for the cell. For this they must define the simulation time (5 minutes is advised) and based on this time calculate the time needed to be able to satisfy the customer demand. They should use production system representation techniques learned from other course units in the same year or previous years and all methods (e.g. balancing methods, layout methods) and tools they deem appropriate to represent the production system, flows, and layout.

Students should also include the automation design proposal that improve line/cell performance, including the complete automation project specifications, selection of sensors and actuators, Grafcet and ladder diagram of the proposed system.

The documentation submitted should contain information relevant to the assessment of OPSI and PCA and explicitly include the contribution of each group member in the development of the work. The type of documentation submitted for evaluation could be video, Powerpoint, simulations, poster, web page, blog, mural. The public presentation in the class should include the demonstration of the production cells to obtain the designed product through an operative mode and measuring some performance variables: productivity, number of units produced, Work in process (WIP), or others found relevant.

KEY FINDINGS AND DISCUSSION

Figure 1 shows one of the implemented U-shaped tennis shoe assembly lines. In class, students performed the real-world assembly of tennis shoes, presenting the defined production steps, the machines, the working process and the associated operating times as well as the designed automated systems.

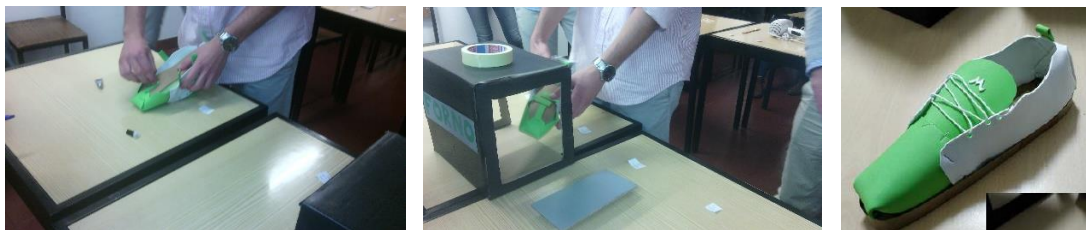


Figure 1 Example of a tennis shoes assembly line in U-shaped layout.

Through observations it was possible to highlight the involvement and the enthusiasm of the students and the networking and meetings in company (for those who select to do the study in industry). Also, it worth registering the high number of concepts employed in the design, not only from the two course units but even from previous course units (e.g. safety concerns), allowing instructors to infer that students correctly applied different technical issues in the production line.

Also, the feedback obtained from a survey done at the end of semester inquiring students about assignment satisfaction was very positive. The competencies related to the conceptual elements characterized by Rychen and Salganik (2001), namely responsibility, initiative, learning

satisfaction and motivation by challenge, received scores higher than 4 [1: Totally disagree to 5: Totally agree].

Additionally, the feedback from the open questions about what most pleased the students included: class concepts put in practice, the challenge, the work developed in companies, teamwork, autonomy, the importance given to a practical work instead of a theoretical test. What pleased them least were the unequal workload among team members, short duration for this assignment, the missing assessment criteria, difficulties in product presentation in a classroom, the lack of synchronization among company and teacher objectives, the difficulty in interpreting the task statement. Regarding points to be improved, students point out team organization, task statement, clarification of the assessment criteria, prior contact with the companies, selection of the operating mode, and to extend this task to other course units to become a Project-Based Learning (PBL).

Most recommendations were taken in account for the second edition, mainly, the task statement was improved and the assessment criteria were clearly presented. Others were not accomplished because it was not the main objective, for example, to have a previous contact with companies promoted by the teachers. As it is not mandatory to develop the project in a real-world industrial environment, teachers do not consider selecting possible industrial partners. At the same time, it is expected students develop their soft skills, initiative and networking. Additionally, the students of 4th year of the program do have PBL collaboration in a company so this was not the objective in the 3rd year.

CONCLUSIONS & RECOMMENDATIONS

Students from the third year of the Integrated Master of Industrial Engineering and Management designed and implemented a simulated automated assembly line (virtual or company-inspired), where they applied the theoretical and practical concepts taught in two course units.

Although some student projects did not present elaborate projects, they respected the integration of the proposed topics (and also the topics of other course units, when necessary) and suggested a well-defined solution. It is also worth noting the enthusiasm of students during

the project development and on the presentation day and also the positive assessment they achieved.

As limitations of this teaching/learning experience it is worth mentioning the high number of students in each group and the room conditions for working in groups and for public presentation of the projects. Ideally groups should be of four students and classes should not run in auditoriums. In this semester, the second edition is running taking into account student suggestions from the first edition.

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Theme 2: From Outreach to Lifelong Learning: Practice, Policy & Paradigms in Engineering Education

Introduction

From the time we are born, engineering impacts every activity and aspect of humanity; from the design and maintenance of neonatal units, through to the planning and provision of elderly care, there isn't a single stage of life where engineering isn't fundamental. Given this, the need for every aspect of education to encapsulate an appropriate level of engineering. To do this there needs to be a paradigm shift in how society views and values engineers. At the moment, in the UK at least, engineering is generally absent from the pre-college curriculum with no requirement to educate or enthuse the next generation about the invaluable role played by engineers in conceiving, designing, building and maintaining everyday life.

The eclectic nature of engineering is reflected in this section which covers a wide-range of topics from outreach activities with school pupils, through to the provision of open-days and how change may be managed in higher education. Other challenges facing engineering education around diversity and inclusion are also discussed with a range of perspectives being offered.

The general assumption across society is that engineers are those responsible for building and repairing things. The professional role played by engineers in imagining, innovating and implementing forward-thinking change needs to be widely promoted across society. To do this, a paradigm shift is needed whereby the chains of the 18th Century Industrial Revolution are discarded and engineering reconceptualised as a future-facing, exciting career which involves so much more than simply building or repairing things.

To misquote a famous Sociologist *"Engineers of the world unite, you have nothing to lose but your nuts, bolts and chains..."*

Jane Andrews, EIG, WMG, University of Warwick

Reflection for Learning and Practice in Developing Engineers

Gibbs, Beverley^a & Wood, Gary C^a

Department of Mechanical Engineering, University of Sheffield^a

b.gibbs@sheffield.ac.uk

KEY WORDS: Reflection; Engineering Education; Professional Practice; Curriculum Development; Transferable Skills

SUMMARY

This short practice paper provides an account of our work, over five years, introducing student reflection as an aid to effective learning. We share four interventions that provided reflection opportunities with varying degrees of formality and at various points in the learning process. Interventions took place with MSc and MEng finalists, all at FHEQ Level 7. We offer a high-level evaluation of these interventions, and share our conclusions on the purposes, efficacy and power of reflection for engineering students. Our experiences have caused us to focus much more closely on the structuring power of various stimuli for reflection, and the learning design choices that influence the long-term impact – reaching into professional practice – that students can glean from reflection in learning.

INTRODUCTION

The role of reflection in engineering education and practice has never been more evident. It is considered an integral part of becoming an engineer: for making sense of work experience (RAEng 2015); for engineering students to maximise the benefits of learning by doing (Ambrose 2013, in Turns *et al* 2014); as a foundation of project-based learning (Broadbent & McCann 2016); as a way of improving one's own mental processes when faced with complex tasks

(Hazzan & Tomayko 2004); as an important element in the development of teamworking skills in engineering design (Hirsch & McKenna 2008); and as an underpinning of critical thinking necessary to achieve 'adaptability' as an engineering habit of mind (Lucas *et al* 2017). Indeed, Popper described the capacity to learn from mistakes as being the foundation of scientific progress (1962).

In this paper, we describe and evaluate our own interventions to promote reflection in students in mechanical engineering curricula. We explain our specific aims in this respect, our interventions, and the learning we have experienced.

LITERATURE REVIEW

Reflection is a process of considering something deeply, a process of thinking about our feelings and responses to events, and analysing them in order to learn and develop. Many mechanisms have been tried and evaluated to realise this process: diaries, self-assessment, learning journals, meeting minutes, and notebooks (Svarovsky & Shaffer 2006); learning essays (Turns *et al* 1997); bespoke activities as stimuli for reflection (Hazzan & Tomayko 2004); portfolio reflection and end-of-course 'metareflection' (Kavanagh & O'Moore 2008); or writing and literacy interventions (Arnó-Macià & Rueda-Ramos 2011). Despite this innovative base of activity, systematic interventions remain elusive (Kavanagh & O'Moore 2008).

In this short practice paper we acknowledge this well-established need for reflective capacity in engineering students and engineers, and use Moffatt and Decker's work (2000) as our point of departure: '...there is no silence quite so pregnant as the one when engineer, both faculty and students alike, are asked to talk about how they feel'. This observation surfaces the affective, as well as cognitive, aspects of reflection (Leitch & Day 2001), and reflects the difficulty that students of engineering find with applying reflective models to explore their own performance and practice.

CONTEXT

Building students' capacity for and enabling them to see practical utility in reflection has been a key consideration in recent curriculum changes, including a whole programme curriculum redevelopment upon which we recently embarked in our Department of Mechanical Engineering. Promoting students' reflection is an important component of our curriculum design for five main reasons:

1. To enable our students to be more independent learners, able to identify and respond to their own learning and development needs during their studies and through commitment to CPD.
2. To empower students to personalise their learning, setting and working towards individual development goals aligned with their future career aspirations.
3. To foster the development of intellectual capabilities through integrating learning across modules (Wood & Gibbs 2019).
4. To prepare our students to work in reflective teams and organisations where the value of reflection moves beyond individual development and into considerations of ethics and professionalism.
5. To address the complex challenge of attainment gaps between MSc and MEng students (both at FHEQ Level 7). Multiple issues affect this gap including language ability, learning traditions, and quality of incoming cohort; approximately 90% of students are international, without English as a first language. Transition into University for such students is rapid, with one introductory week and then a full loading of project and modules.

Although utilising reflection allows us to respond to these challenges, introducing and using reflection is in itself challenging. Authentic reflection requires identification of opportunities to reflect – that is, identification of critical incidents, periods or events that warrant and provide an opportunity for learning through reflection, and where reflection can be valuable. Our

existing instances of utilising reflection in our learning experiences removed the need for students to identify such opportunities: we selected the incident, period or event in framing the reflection task, often as an assessment. The focus of reflection being an assessment also frequently aligns it with the end of modules or phases of learning. In consequence, there is limited value for students in the reflection that we require them to undertake, beyond achieving a grade. Their motivation for the reflection is not genuinely their own development in itself (save, perhaps for the development of the reflective skills *per se*), and whenever the assessment is completed at the end of a learning unit, its value is limited in terms of potential to change future behaviour, particularly in the context of a modularised degree where students frequently fail to transfer learning and make connections between units. Addressing these issues became our sixth challenge:

6. To teach students to identify opportunities to reflect, so that they recognise the value of reflection as a lifelong learning and development tool, valuable to their continuous progression as a professional engineer.

We present below interventions that have focused on addressing these six challenges. Our broad aim was to assess whether structured reflection processes could be used to support students in becoming more agile and independent learners and more ethical emerging practitioners, able to connect different parts of the learning experience with their own reactions and feelings, whilst taking ownership of learning goals and decisions more effectively.

OUR INTERVENTIONS

The first intervention was the introduction of a learning diary as part of a dissertation module, in the 2015-16 academic year, for 50 MSc Engineering students taking a 'with management' minor; this included students on mechanical, bioprocess and energy engineering variants. Approximately 90% of the students are international, most commonly from China. Students completed the diary via Google Docs so they could receive feedback from the course instructor, and were encouraged to record approaches, their reflection on those approaches and their revised approach.

The second intervention took place via a new 10-credit (100 learning hours) module called *Adaptive Decision-Making in Engineering Contexts*, introduced in the 2016-17 academic year. The

module consisted of high levels of small group work and communication-based activities designed to address critical thinking and efficacy of learning and professional practice. Students completed an online portfolio workbook in PebblePad, with six compulsory reflection submissions, each weighted at 5%. Students were given a proforma to support structured reflection processes in the style of Graham Gibbs's work (1988), and could receive feedback on each attempt before submitting the next (or not, as they preferred). Students were encouraged to think broadly about formative moments – from the module, other learning experiences in the course, or their adaptation to postgraduate study or life in the UK.

The third intervention, also in *Adaptive Decision-Making in Engineering Contexts*, took place in the 2017-18 and 2018-19 academic years and evolved the previous model towards a firmer focus on decision-making as an individual and personal skill. To give students more autonomy, reflections were made optional, but recommended for use in the portfolio. The same training and proforma were offered.

Our fourth intervention comes from *Preparation for Practice*: a final-year MEng (FHEQ Level 7) module in which students have 100 hours to work towards a learning goal they set, using learning activities they identify, with the aim of personalising their learning and becoming the best graduate they can aligned with their career aspirations. Introductory workshops provide tools to encourage and stimulate reflection. Students then make their own choice of learning activity, supported by a staff mentor, with whom they meet formally twice across the year, and whom they can consult through drop-in sessions and open office hours at other times, to discuss and help them reflect on their learning. A key difference between reflection in this module, and the interventions described above is that in *Preparation for Practice*, reflection forms a starting point for action. Students must consider their current profile, compare it with the ideal profile for their next career move, identify areas to strengthen, and then set a learning goal. This is followed by self-identifying activities that could help meet the learning goal, and evaluating them to select one to pursue, which involves individual reflection at the level of interests and motivations, and understanding how they learn best. After completing the activity, the students write a reflection on their experience and the extent to which it met their learning needs, whilst also looking ahead to how their learning will benefit them, and what further learning needs they foresee, so instilling a commitment to CPD.

EVALUATION OF INTERVENTIONS

The first intervention (learning diaries) produced voluminous information that was quite difficult (but not impossible) to mark effectively. The format did not provide for key learning moments to be presented with clarity, nor for 'next steps' to be consistently identified. It was also the case that students with mental health difficulties through the year found this a challenging and distressing task, and this was a significant influence in moving away from an unbounded disclosure of thoughts and feelings towards a more focussed portfolio.

The structured portfolio introduced in the second intervention worked well, as did the low-weighted reflective submissions and opportunity for formative feedback. As stimuli for reflective moments, students drew on a fascinating variety of topics, including cultural adaptation, dynamics of learning teams, in-module stimulus activities. Because of the structure of the assessment, a significant number of students thought they were supposed to reflect on the week that had passed (e.g. 'Week 4 reflection') which meant they lacked insight and the "a-ha!" moment. Those who submitted them for interim assessment got feedback, but students finding the right stimulus for reflection remained an issue.

The third intervention, in *Adaptive Decision Making for Engineers*, evolved the in-class activities towards decision making tools and a clear workshop approach, and made reflections optional rather than mandatory. The aim of this was for students to see the value of reflection, rather than completing it mechanistically for assessment purposes. Unsurprisingly, the rate of reflection fell back: just under half of all students included structured reflection as evidence in their portfolios.

Finally, in *Preparation for Practice*, students begin with reflection – not as an explicit activity, but through a need to identify skills they want to build further before graduation. This module launched in 2019-20 and so is still in progress. However, initial observations reveal that students are able to reflect effectively to identify areas they wish to develop, and to take into consideration their current profile and what will be required of them as a graduate in their chosen career. However, students have been less confident in taking action as a result of that reflection, frequently seeking permission from staff mentors first. We believe this stems not

from reflection itself, but from the fact that the module is unique in requiring students to take responsibility for their own learning plans, and they are not used to this through an education system that is highly structured by staff-led programmes of learning.

DISCUSSION

Our goal throughout our interventions and changes has been to equip students with skills to reflect, and an appreciation of the value of doing so, both in a learning context and in the context of their future professional practice (as engineers). Working towards this goal has required us as practitioners to reflect on the way that we, and others across the sector, are using reflection in learning experiences. We have come to recognise that reflection is utilised in two ways:

- (1) To build the skill of reflection itself, informed by evidence that this is an important capability for professional practitioners;
- (2) As a way of promoting development of students' practice as learners, learning from experience over time, for example in responding to assessment feedback and applying that learning to future work.

As is evident in our examples of practice above, as we have attempted to respond to our goal, and developed our thinking, we have made two important changes: reducing our control over the process, and the formality of opportunities to reflect.

We have shifted our approach away from reflection being a requirement for students at particular (often end-) points in their learning, on aspects of the learning we determine, to more flexibility and choice over when students engage in reflection and what the subjects of that reflection are. This is important because prior to our intervention, reflection for our students started from a stimulus point we identified, whilst if our graduates are to utilise reflection effectively as part of their professional practice, it is important that they can identify the critical events, incidents or periods that form stimuli for useful reflection as an opportunity to improve or maintain performance.

In shifting the focus away from end-point reflection, we have also attempted to reveal the value of reflection to students by making it more timely. When reflection occurs separated in time from the critical incident on which it is based, the power of the reflection is lost because it becomes less detailed and because the opportunity to take action resulting from the reflection is limited.

Our change in practice has been characterised by a reconsideration of the formality of reflection opportunities in our curricula, stemming from our observation that since reflection has usually been tied to assessment in our practice, it has necessarily been formalised into written pieces, through journals, blogs, portfolios, etc. This is warranted to the extent that we want to be able to give feedback to students and help them develop their approaches to reflection: achieving that aim requires us to make the process explicit and visible. In reality, however, this turns reflection into an academic exercise which is not characteristic of its use in a professional setting, where it most often lacks this level of formality; rather, it is a process of thinking around problems, identifying new ways of approaching situations, drawing on previous experience and perhaps input from others through conversations and asking questions.

In reimagining the way we use reflection in our learning experiences, as described above, a significant consideration was securing approval for assessments that provided scope for the flexibility and student choice required to make reflection more meaningful. This has not proved straightforward, and has taken progression through our interventions to build evidence and confidence amongst colleagues in our assessment review processes, to overcome initial rejection of students determining their own learning outcomes. We make this point partly as an observation of the impact of our early work, but also as a note of encouragement to others considering utilising our approaches who may face initial resistance.

CONCLUSIONS & RECOMMENDATIONS

The work on reflection reported in this paper is still very much in progress, with our most recent interventions aiming to facilitate students' recognition of stimuli for reflection, and of the value of engaging in reflection for their development and success, only having recently been implemented. Nevertheless, on the basis of our learning thus far – indeed, to further that

learning by testing approaches in different contexts – we make some recommendations for further exploration.

Underpinning our recommendations is a sense that we have thought about reflection too simply, and this has led to a focus on teaching students how to do reflection, framed as an academic exercise (for assessment), without conceptualising it as a lifelong practice. Much work has assumed that teaching students to do reflection in learning can prepare them for reflection in practice as professional engineers, whilst our work exploring this area suggests that achieving such a transition requires more work and thought on our part to enable students to see the value of reflecting in both contexts.

Our first recommendation is that we need to think more carefully about what forms the stimulus for reflection and how it is identified. As we have noted above, the stimulus is frequently determined by the teacher since the reflection is an assessment. This has two significant consequences for students' development of skills in reflection: it prevents them from seeing the true power and value of reflection in guiding and developing their practice – the 'a-ha' moments, we describe above – because the process becomes an academic exercise; and it means that students are not equipped to spot stimulus points to trigger their own reflection, because we are not giving them the freedom to do so. Therefore, students never reach the intrinsic value of doing reflection and it does not become a core part of their professional practice. Encouragingly, our early work in *Preparation for Practice* indicates that students can undertake self-initiated reflection when given the opportunity, albeit with a need for some support, particularly in having the confidence to act on the outcomes of their reflections in changing their practice.

Our second recommendation is that we give further consideration to the points at which reflection happens in our programmes. This also relates to the use of reflection as a method of assessment, which shifts the focus onto reflection coming after learning in a module, limiting opportunities for it to provide feed-forward into future work. In *Preparation for Practice*, students choose to undertake development activity that aligns with their career aspirations as they approach graduation. This inherently requires reflection to inform decision-making – not because we tell students to reflect, but because they need to do this in order to explain why they make the choices they do. As a result, students engage in a reflective process that genuinely

results in action. Making reflection the starting point, rather than an endpoint reveals its true power to students.

Our third recommendation is that we need to provide opportunities for reflection of different levels of formality. This is a challenge, because our utilisation of reflection as a means of assessment frequently leads to its formalisation in written pieces which do not mirror the less formal way that reflection is often used in practice. We need to support students to undertake reflection as a process of systematic stopping and thinking, seeking and responding to different perspectives, and determining outcomes and future directions. If we can achieve this, not only do we equip our students better for life as reflective practitioners in engineering, but we have the potential to resolve the widely recognised issues of students not responding to feedback they receive through their learning journey.

The potential benefits of students internalising stimulus moments for reflection are wide-reaching. On the one hand, reflective skills provide the foundations for lifelong learners who can engage proactively with the CPD agenda so valued by the Engineering Council, and so important to the concept of sustained competence in all engineering codes of conduct. At the societal level, engineers who can reflect as an integral part of their practice, and be open and transparent in that reflection, lie at the heart of reaching a more responsible innovation for the twenty-first century.

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Listening and Learning: Confronting Culture and Constructing Change

Knowles, Nicola^a, Andrews, Jane^a

WMG, University of Warwick

n.j.knowles@warwick.ac.uk

KEY WORDS: Change Management: Consultation: Innovative Student Experience

ABSTRACT

This brief practice paper provides a short discussion of the first stages of an Action Research Project put into place to inform and ground organisational change within a large Engineering Department in a Russell Group University. The findings of focus groups with professional support staff are being used as a basis for what will be a critical educational management research project purposefully designed so as to inform and underpin cultural and practical change. Presenting a summary of the findings as opposed to primary data, this paper is written at what is the very early stages of a large cross-departmental change strategy. It concludes by acknowledging that whilst organisational change is never easy, by listening *to* and learning *from* colleagues a better and brighter future is in the process of being achieved for all stakeholders including students, employers and colleagues.

INTRODUCTION: ORGANISATIONAL CHANGE AT A TIME OF UNCERTAINTY

Contextualised by the socio-economic ambiguity of Brexit that is preoccupying government and business at all levels, the infrastructure of the UK sits on a knife-edge (Kierzenkowski et al, 2016). Within this environment university education faces unprecedented uncertainties in terms of future research funding, student numbers and the reputation of the British Higher Education on the world stage (Mayhew, 2017). One of the key externalities of Brexit and the surrounding political situation is that Engineering Education, like much of the UK Higher Education Sector, is enduring a period of insecurity as Engineering Faculties struggle to attract and retain suitable numbers of appropriately qualified students onto undergraduate programmes (Becker, 2010; Finegold, 2016; Andrews & Clark, 2017). Yet debates regarding the role that the engineering profession plays in maintaining and advancing society's infrastructure continue and have recently emphasised the negative impact that potential future shortages of engineers could have on the country's economy and standard of living. In discussing this Engineering UK argues: "*Shortages in highly skilled labour are expected to be exacerbated by the growth of new industries, some of which scarcely yet exist, emerging from new technologies and knowledge*" (2018, pg. 9).

Sitting within this indeterminate yet volatile societal context is WMG, a large engineering department at the University of Warwick. Mainly educating postgraduate students, WMG also houses a wide range of undergraduate programmes including degree apprenticeships and traditional courses; reflecting an academic portfolio that has been purposefully designed so as to meet the future needs of industry and the economy. Like many Engineering Faculties, WMG faces a number of socio-pedagogical challenges including the need to promote widening participation and social mobility across the student body (Bertaux & Thompson, 2017; Fowles-Sweet & Barker, 2018). Additionally, ongoing concerns about how to best teach new undergraduate students ill-equipped to study degree level engineering in terms of levels of maths and science continue to challenge engineering educators working across department (Mann, 2001; Kuh, 2009).

Tasked with developing and leading change across the undergraduate portfolio within WMG, one of the paper authors has recently started to critically examine the current educational offerings and strategic vision of the department. Engaging the second paper author, an

educational researcher, to assist in the critique, the first task has been to develop an action research approach. It is the early findings of the exploratory stage of this approach that this paper reports upon providing a brief analysis of the findings of focus groups conducted with undergraduate professional support staff.

METHODOLOGY

Mirroring the stages of 'Action Research' of *observe, reflect, act, evaluate, modify, move in a new direction* (McNiff & Whitehead, 2006, Pg. 9) exploratory observations are underway. The first stage of this has been to undertake a 'touchpoint' exercise with colleagues employed as professional support staff within the undergraduate office. This exercise involved 'active focus groups' in which colleagues were actively encouraged to use artefacts, drawings and story-telling to reflect upon their own experiences and insights. Aimed at identifying colleagues' perceptions of the key issues and challenges currently influencing the undergraduate experience within the department, over a period of just under four hours seven colleagues (two males and five females) were led through a series of fact finding exercises and focus groups facilitated by the project lead. A contemporaneous record of the discussions and activities was taken by the researcher who then, following grounded theory techniques (Glaser & Strauss, 1968), undertook an initial analysis of the data to identify four key themes. These themes will be used to direct and inform the next stage of the project.

EMERGENT FINDINGS.

Using axial and simple coding the four main themes that have emerged out of the exploratory data each represents a key challenge that colleagues identified as currently impacting the department:

1. The Mitigating Circumstances Process
2. Personal Tutoring

3. The 'Wellbeing' Team

4. Individual student support.

During the activities each of these issues was repeatedly discussed with colleagues' expressing a range of opinions. Whilst it is too early in the process in terms of data collection to provide a full qualitative thematic analysis, there is sufficient data to begin to effect change at a practice level. Hence each of these themes is now briefly discussed.

INITIAL FINDINGS

I. The Mitigating Circumstances Process.

The process by which students are supported through mitigating circumstances was the first issue discussed by the group and there was a general consensus that the process is in dire need of change. The main issues identified by the group were:

- A lack of coherency across modules, courses and programmes. Colleagues described how each 'module' or 'course' has its own policies procedures and practices around how students report and are supported through the mitigating circumstances process. Concern was expressed about a lack of departmental consistency in terms of process, scheduling and reporting of panel decisions.
- The Mitigating Circumstances panels comprise three academic colleagues who work closely with the students. Colleagues from the undergraduate office related that, on occasion, they believed that this relationship could result in a conflict of interest.
- Colleagues claimed that there are no clear guidelines with regards to the timing of panels and how long it takes for students to be given feedback. This matter proved particularly challenging to those whom are student-facing.
- Likewise, colleagues expressed misgivings about the occasions when they need to ask students for evidence of a death; noting that this can be traumatic for both parties.
- The final matter discussed under this subject heading also related to the presentation of 'evidence' from students. Again, across the department, the professional support

staff suggested that there is a lack of consistency which ultimately results in supporting evidence differing from programme to programme.

2. Personal Tutoring

Concerns were raised regarding the Personal Tutoring System with colleagues describing allocation of Personal Tutors as something of a 'lottery'. A number of distinctive challenges were raised:

- There is a belief that some academic colleagues do not fully engage with the Personal Tutoring system due to a range of work-related pressures and a lack of understanding about what the Personal Tutor role is.
- Likewise, colleagues notes that students also do not engage in Personal Tutoring, preferring instead to make contact with support staff or module tutors and project supervisors when they need help.
- During the discussions it emerged that the colleagues felt the scheduling of Personal Tutor meetings in the timetable did not work for a range of reasons complexities associated with the teaching timetable.

3. The Wellbeing Team

Part of the wider university provision, colleagues felt that the wellbeing team do not have a high enough profile and that students are generally unaware of where to go for individual, social or personal support.

- The suggestion that a WMG Wellbeing Team be put together was discussed and widely supported.

4. Individual Student Support

Colleagues agreed that 'face-to-face' contact with students is the most preferable, with the best outcomes:

- It was noted that the location of the UG team (at the back of a massive shared office) means this is not always possible.

- The idea of a 'drop in / front desk' was discussed and supported. Likewise, the possibility that the whole team may be relocated so as to easily accessible to students was discussed and a consensus reached that this would be a positive move.

WHAT NEXT?

Using the findings of the exploratory focus groups and interactive activities to inform and guide in-depth research across the department, a semi-structured qualitative interview guide has been developed with which to closely examine and critical examine academic colleagues' perceptions of WMG's undergraduate programmes. To date, one academic group has been interviewed and arrangements are underway for colleagues in the remaining teaching groups to be sampled.

At this point in time it is too early to make any strategic decisions based upon the emergent findings; however, in adopting a proactive approach to enhancing the student experience a number of immediate interventions have been put into place including:

1. A review of the Mitigating Circumstances Process is underway commencing with a critical analysis of the wider university regulations, practices and policies. One of the issues to be discussed in the subsequent qualitative research is the need to closely examine the academic viability of the process.
 - Until an improved process has been put in place colleagues in the undergraduate office have been directed to notify senior management when concerns or complicated cases arise.
2. Working with WMG's Education Innovation Group a series of staff development workshops are underway. Focusing on a range of topics from scholarship through to programme design and innovation in learning and teaching; the workshops are open to all colleagues.
3. Plans to improve Personal Tutoring across the department have begun to be enacted with detailed guidance about how students should be supported put into place.
4. The issue of student support continues to inform and guide the project, with academic and professional staff being encouraged to offer individualised support.

CONCLUSION

This practice paper provides a brief insight into what will be a major cultural and organisational change within WMG. Purposefully selecting to ground change in academic research, the initial groundwork has set the tone and standard for the project. In conclusion, organisational change is never easy but by **listening to and learning from** colleagues and then students, the project lead is determined to make sure that undergraduate engineering at WMG continues to lead the UK with a flexible employment focused curriculum delivered and supported by evidenced based scholarship, pedagogy and student support.

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Mind the Gap; Bridge to Engineering

Ladwa, Neil

Warwick Manufacturing Group, University of Warwick

neil.ladwa@warwick.ac.uk

KEY WORDS: Curriculum Alignment; Collaboration; Maths Transition; Widening Participation; Work-Based Learning

ABSTRACT

This paper relates to research which seeks to explore the barriers to widening participation (WP) in engineering and digital degree apprenticeships. It presents a collaborative methodology which has generated conversations with industry partners centred around challenging the traditional (A-level) maths and physics knowledge base which students have been expected to bring onto undergraduate programmes. The study has asked “What is the ‘gap’ between the entry level understanding and confidence and we expect of our undergraduates?” It also looks at what those degree apprentices from more diverse educational and experiential backgrounds bring to a degree apprenticeship.

INTRODUCTION

One of the primary ambitions for the degree apprenticeship programmes discussed in this paper is that they will be both accessible and attractive to a wide variety of learners, this includes those with BTEC qualifications and students who have completed 'lower' level apprenticeships. Many such students are already in the workplace and have been identified by their current employers as being suitable for upskilling and reskilling.

Highly numerate degree disciplines, such as engineering, present a particular challenge to realising widening participation and as such have previously tended to attract only those students who have 'GCE 'A' level grades in Maths and / or Physics.

This paper relates to the early stage of an Action Research study in which a collaborative working group of stakeholders have sought to critically examine the pedagogical and practical challenges and strengths of an Applied Engineering Programme undergraduate course within a Russell Group University.

RATIONALE

Starting with the thesis that there is a gap between the academic requirements needed for success on the Applied Engineering Programme (particularly in relation to the subject of Maths and Physics) and the previous experiences, qualifications and abilities of the students, our study seeks to identify a way of proactively widening participation on engineering degree apprenticeships. One way of widening participation is to lower entry criteria for degree apprenticeships, however, this risks putting undue demands on those from non-traditional entry routes as they struggle to 'catch-up' (with corresponding increase in likelihood of non-continuation). Conversely, maintaining existing standards of admission in terms of maths and physics ability, risks exclusion such students.

It is this conundrum that this paper considers. Presenting the findings of exploratory research which investigated the gap in academic requirements and prospective student prior achievement and education a combination of methods were used. The results of the study are being used to inform the development of a bridge across the gap(s) and so to widen participation in engineering and digital degree apprenticeships.

RESEARCH QUESTIONS

Prior to setting the primary research question, a number of benchmarking statements needed to be agreed upon. The first of these required the articulation of which widening participation groups are the degree apprenticeship programmes aiming to encourage. Having taken the decision to focus on students from non-traditional backgrounds in terms of prior educational qualifications, the following research question was developed:

How can the Degree Apprenticeship Programme encourage higher numbers of students from a non-traditional educational background?

Having decided this, the aim of the study became to identify “What factors are required in a solution that allows the university to admit ‘WP’ students but does not present too high a risk of failure for the individuals and employers involved?”

These broad questions about the aims of widening participation are addressed in a specific local engineering education setting. The objective is to secure results to inform recommendations curriculum alignment. The research is influenced by John Biggs (1993) work in this area. In particular his 3P model: Presage; Process; Product. It is on the ‘presage’ stage that much of our talk of curriculum alignment is focussed, i.e. the things that have occurred prior to the learner engaging with a process of learning on a given degree apprenticeship programme. Some of the factors that presage learning can be thought of as based in the learner (e.g a student’s prior knowledge, motivation, ability). Other presage factors are based in the context of the teaching institution (the intended course content, the planned methods or assessment etc.)

A common concern throughout is to improve transitioning from secondary to tertiary level education: developing an awareness through curriculum alignment of what students will expect to study at university and also an awareness within the university: to know what skills and prior knowledge students arrive with, and what can make a student’s learning journey smoother and more aligned.

Meyers and Nulty (2009) have built upon the Biggs 3P model further by identifying five curriculum design principles to align authentic learning environments, assessment and student approaches to thinking and learning outcomes. These design principles refer to courses being:

- Constructive, sequential and interlinked;
- Aligned with each other and the desired learning outcomes.

Thus, a final year secondary level programme would align or feed more naturally into a first year tertiary level undergraduate program through curriculum alignment.

METHODOLOGICAL APPROACH

- The Engineering Education Context

A working group was formed which very much resembled an apprenticeship standard trailblazer in that it included representatives from the automotive industry, Warwick Manufacturing Group, (WMG), and a local sixth form. This mix of individuals allowed for joined-up thinking about the learner journey; to establish issues from different perspectives on what the 'gap' is. Follow-up meetings were held to consider aspects of bridge-building, what would be required to help learners overcome any gap

- The Applied Research

Adopting a mixed methodological approach a total of 25 manufacturing degree apprentices were sampled from years 1, 2 and 3 of a four year programme.

Data analytics were used to access and analyse student performance in relation to maths. The data analysed related to entry qualifications; a maths diagnostic test results; and performance in maths modules at university.

Unstructured qualitative interviews were held with the apprenticeships with the aim of gaining a depth of information about their individual learning journey and background story of individual apprentices.

- **Postcode Analysis**

An analysis of students postcodes found that a small minority (14%, 3 out of the 21 home postcodes) were from a low participation or high deprivation areas. Of those 3 students 2 were from a BAME background and one has been identified with as having additional learning support needs. The 3rd student identified in the postcode analysis is a white male who has a mix of qualifications including both BTEC and A Level (including 'A' Level Maths grade A).

THE ENGINEERING EDUCATION PROBLEM

One of the industry partners on this project supplied a case study that encompasses the nature of the engineering education problem our work is addressing. They describe their experience that candidates entering our Applied Engineering Programme (undergraduate course) have struggled if they have come from a BTEC engineering background, without a maths A-level. They report that this has been the case even after 2 years of Foundation Degree study. As a result, they have recently changed their entry criterion to demand an A-level grade C minimum for entry to the programme.

The industry partner is keen to explore how this shrinking pool of candidates for the programme can be increased; how the programme might be made accessible to those with aptitude and interest, but no maths A-level. The partner has some experience of re-engaging employees in a maths programme to enable them to undertake an HNC. Although some still struggle, they have found that success chances improve when maths support is delivered in parallel with other materials. Candidates committing to a 4 year (degree apprenticeship) programme is a significant undertaking (for participant and employer) – so a 'bridging' programme that prepares and validates a learner for progression into a degree apprenticeship is required.

Yet, before we can bridge the gap, we must assess what *kind* of a gap it is and how *wide*. Hence the work outlined in this paper.

EMERGENT FINDINGS

In summary the study so far has found:

- Apprentices that enter the degree apprenticeship with a BTEC are more likely to have been accepted after a diagnostic test resit
- Apprentices that enter the degree apprenticeship with a BTEC flag up more maths additional support requirements,
- Higher Maths grades results in higher diagnostic scores
- Having a Maths A Level regardless of grade means a better likelihood of passing maths on the degree apprenticeship
- The apprentice's diagnostic scores correlate to similar corresponding module grade results.

DISCUSSION

Whilst having a BTEC increases the likelihood of failure and issues struggling and failure is not limited to BTEC with significant numbers of A Level students also experiencing difficulties. Do not underestimate individual learner 'factors' such as persistence and resilience. This can be accounted for in employer assessment centres. Diagnostic scores can account for students without math qualifications but who have maths ability that has been uncertificated.

Factors that have not been established robustly: impact of assessment, teaching styles and specific syllabus issues. Gender was another factor that could not be accounted for with any confidence. Of the 25 apprentices involved in this study only 1 was female. Along with gender age and past experience again was another factor that could not be taken into consideration. This was due to the sample of learners having little variation in age. The vast majority were 18 year old school leavers, (12). 9 were 2nd year apprentices and all recruited straight from school as were the 4 3rd year apprentices also.

Johnston-Wilder & Lee (2010) identified a number of ways of improving maths 'resilience' in students noting that the way in which maths is taught often acts as a barrier to learning. Another huge issue is around learner self-efficacy and resilience in relation to maths. This is an age old issue as documented by Dowker et al (2016) who examine the problems around 'maths anxiety' arguing that *"One possible reason for the negative association, (correlation) between mathematics anxiety and actual performance is that people who have higher levels of math anxiety are more likely to avoid activities and situations that involve mathematics."*

Informal interviews conducted with the apprentices as part of the exploratory phase of the study highlighted that these learners are highly motivated with a strong desire to succeed. Such positive attitudes lead to questions being raised about exposure to maths and differences in amount of time spent on maths between BTEC and A Level learners. This reflects the initial finding that students who had completed A Level maths regardless of grade tend to perform well on maths modules.

CONCLUSION AND RECOMMENDATIONS

In conclusion, maths anxiety is not a new issue. The main recommendation from the work undertaken thus far relates to the need to increase maths exposure throughout the curriculum in such a way that learners' confidence may be slowly enhanced. Scaffolding and building learner's confidence around maths gradually over a period of years requires a joined up thinking approach requiring collaboration and flexibility with the onus on education practitioners to provide a curriculum across sectors that prepares learners for engineering. For WMG the journey is at the beginning. It is hoped that by identifying key barriers to engineering apprenticeships will enable a policy of widening participation to be adopted from this point moving forward. In this way a much richer talent pool of young people will access and succeed in an engineering career.

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Increasing Science Capital: Engineering Students Inspiring and Engaging New and Future Generations

Patricia Muñoz-Escalona^a, David Rigmand^b and Meg Dunn^c

^aGlasgow Caledonian University; ^bBrediland Primary School, Paisley, UK;

^cUniversity of the West of Scotland

patricia.munoz@gcu.ac.uk

KEY WORDS: STEM, Partnership, Engineering, Collaborative, Primary School

ABSTRACT

A STEM partnership was built between Glasgow Caledonian University and Brediland Primary School with the aim to inspire and engage this new generation to pursue an engineering degree. Students from the MEng Mechanical System Engineering programme worked along P6 Primary School pupils in the design and manufacturing of a wind turbine prototype.

INTRODUCTION:

Collaborative projects allow not only to learn from each other but also allows to enhance confidence, communication skills and teamwork ability among other aspects. Having university students working together with primary pupils in a STEM project provides different benefit to each of the groups involved, where an enjoyable learning environment can be developed. Reports show that in 2017, 42% of the UK population aged 21-64 have achieved higher education qualification (HESA, 2018). However, despite an increase in this figure there is a still a need of role models to encourage and inspire the new generation of engineering (Bhardwa, 2016)

LITERATURE SUMMARY

The UK industry is facing an engineering crisis, as figures indicate that there is a shortfall of 20,000 graduate engineers per year (Randstad, 2019). Another factor that is also affecting the industry is the shortage of women engineers, which has been also recognised as a key challenge and that must be addressed if the UK wants to remain competitive (Daniels, 2019) and if it wants to be the leading nation for innovation in engineering (RAEng, 2015).

To address these issues as academics forming and shaping future professionals in the area of engineering, we also need to inspire the new and future generation in order to contribute to science capital as a fundamental part to sustain our society (Archer et al., 2015). Reports indicate that the earlier children are involved in STEM activities the better as this reduces building up stereotypes (Moss, 2019)

STUDY AIM

This study aimed to:

- Inspire and encourage primary school pupils to pursue an engineering degree.
- Promote and showcase the different types of engineering involved in the project
- Importance of building and working in interdisciplinary groups.

METHODOLOGICAL APPROACH

A collaborative project between MEng university students and P6 Primary school pupil was conducted as part of the STEM partnership developed by Glasgow Caledonian University and Brediland Primary School.

Two different types of surveys with the purpose of measuring different aspects were delivered before and after the project to the two groups involved:

- i) MEng students in the area of engineering
- ii) P6 Primary School pupil

Aspects to be measured from each group

- i) Employability skills for MEng Students
- ii) Likeability in different aspects: reading, writing, maths and engineering.

Table I shows number of participants and demographic details.

Table I. Demographic details of participants

Number/Ager		Gender	Study	Questionnaire type		
1	1/	F	Computer Engineering	Aided	Mechanical	1
2	1/	F	Computer Engineering	Aided	Mechanical	1
3	1/	M	Mechanical Electronic System Eng			1
4	1/	M	Mechanical Electronic System Eng			1
5	1/	M	Electrical Electronic Engineering			1
6	5/ 9-10	F	P6 Primary School			2
7	12/9-10	M	P6 Primary School			2

For the activity five MEng Students from three different disciplines, mechanical electronic system, computer aided mechanical and electrical electronic engineering were matched with thirty P6 primary school pupils (ages 9-10). MEng students acted as STEM Ambassadors and worked together with primary school pupils in the design and manufacturing of a wind turbine. The activity took place over a period of 9 months which included activities that allowed collaborative work, exchange knowledge in the area, increase communication skills, innovating and enhancing practices through real life project. The activity was divided in five main stages:

- i) Introduction of MEng students to Primary pupils to advice on their discipline of study and which aspect of the wind turbine they will contribute to.
- ii) Workshops to develop pupils' understanding of STEM specifically in the areas of:
 - Renewable energy
 - Design and manufacturing
 - Data collection (wind speed)
- iii) Field trip to a wind farm for real life experience
- iv) Visit to university's workshops to see how the wind turbine was manufacture, assembled and tested
- v) Presentation to school and Council representatives

Continued communication between the two groups (MEng students and Primary School) was established in order to keep general updates on the projects. Social media accounts in Twitter and Instagram were created for this purpose. The project has been built bearing in mind the element of sustainability in order to enhance and improve in the future the outcomes of this first version of the wind turbine prototype and continue the partnership with new and future generation. Surveys were analysed to obtain key findings

SUMMARY OF KEY FINDINGS

After the project was completed the engineering area reported the highest increase of likeability amongst the primary school pupils (11%) compared to other topics such as reading, writing and math.

From the engineering topic a likeability higher than 4 (with 5 being the highest score) was given to:

- i) I like engineering (4.22)
- ii) Engineering will allow me to learn many useful things (4.13)
- iii) Engineering interest me a lot (4.09)

From the MEng students' questionnaire where 3 represents very skilled and 1 not as skilled as I'd like, the topic *Participating in Projects and tasks* had the highest increased with 25% (from 2 to 2.67 likeability), followed by *Working with Others* with an overall increase of 21% (from an average of 2.36 to 3) and finally topic *Managing Information* with an increase of 10% from 2.4 to 2.67 likeability.

When analysing the differences between answers related to *What do engineer do in their jobs?* it was observed that before the project 48% of the pupils used the words "fix things/cars/buses" while after the project ~72% of the pupils used the words "design /create things", 23% of pupils included "Wind turbines" and 27% included words as "make cool stuff"

The positive impact of the project can be observed from the pupils' comments:

"I have learned so much about renewable and non-renewable energy! I loved visiting the wind farm and learning from masters' students. I'd love to go to university and learn more about STEM"

"I can't wait until the wind turbine arrives at the school! I hope the anemometer readings I took help us find the best place to put the wind turbine and generate the most energy"

"I didn't think I would get the chance to visit University until I was in high school or even later. It was great! We get to visit labs and take part in wind energy workshops"

The impact that the project had on the MEng Students is best expressed using their own words:

"Being involved in the wind turbine project allowed me to inspire young pupils to practise curiosity and learn about engineering. The project gave me the opportunity to help enthuse the pupils to be involved in STEM, by visiting their school and showing them around Glasgow Caledonian University's workshops".

"My experience of the masters project this year was nothing but positive. The addition of working alongside the primary school for this project is something that I really enjoyed, being able to go out and meet the children, talk to them and feel like I was having an impact on them was the best part of the project for me and it is something I would be very keen on doing again".

"Working with the kids and introducing them to STEM and renewable energy over the past year has been very enjoyable, challenging and rewarding experience. It also presented a challenge in the sense that everything had to be simplified and technical terms couldn't be used,

something I enjoyed adapting to. It was also rewarding to see the kids learn something new and knowing that we had been able to engage and interact with them successfully”.

Working as a team has clearly made an impact in MEng student’s team as their likeability in participating in project tasks increased in 25%. Special attention needs to be taken in this aspect as previous researcher have reported that engineering graduates lack of teamwork ability (Awanga & Daud, 2015).

Having primary pupils and university students working together in a collaborative project develops in them a sense of belonging to a community, where motivation towards STEM topics increases, this helps engagement and interaction and also acts as a driving force to remove labels and stereotypes that have been unconsciously built during many years. This can be related to the results provided by the Scottish Government STEM engagement (Table 2) where a comparison between January 2019 (start of the project) and June 2019 (after project was concluded) can be observed.

Table 2. Children’s perception towards STEM in January 2019 and June 2019

	January 2019	June 2019	Variation
I enjoy taking part in STEM activities and experiences	84%	97%	13%
I think I would be interested in a STEM career	60%	64%	4%
% of girls that enjoy STEM	68%	95%	27%
% of boys that enjoy STEM	54%	98%	44%

Girls were very enthusiastic to see female students as part of the MEng group, and what they have developed as part of their contribution to the design and manufacturing of the wind turbine, and despite this is not clearly evidence from comments provided, it is observed that girls enjoying STEM activities increased 27% as observed from results shown in Table 2. Further work will need to be conducted in the future in this area.

CONCLUSIONS & RECOMMENDATIONS

Collaborative projects between primary pupils and university students provides an excellent opportunity for longer engagement and the feeling of partnerships/sense of belonging to a community that creates links for the children to education and inspire them to pursue a university degree. Creating a sustainable project allows to contribute to science capital alongside an insight into multidisciplinary STEM careers.

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Changing the Inclusion and Diversity Discourse in Engineering: A Manifesto for Change

Peters, Jan ^{1,a}

Katalytik¹ Open University^a

jan.peters@katalytik.co.uk

KEY WORDS: Inclusion; Diversity; Conversations; Staff Development

SUMMARY

Teaching engineering has changed considerably in recent times. The report *New Approaches in Engineering Education* (The IET, 2019), outlined 17 case studies of good, and stretching, pilot and extended, practice. Many of these are based around team activities and problem based learning and offer potential for designing inclusion into the subject matter. Awareness of students' needs coupled with withdrawal of funding support (for disability) has transformed how students can access course material, for example lecture capture and mandatory provision of material in advance of tutorials and lectures commonplace. Often this inclusion is about accessibility.

While the participation of women on engineering courses remains low (but with news of some rises in percentages from a recent Engineering Professors conference) there is still an achievement gap, but a commitment to eradicate it, for black and minority ethnic students. Among these advances there are still those who mention colleagues who still deliver material in the same old way. There are still those who are blind to unconscious biases. And there are still those who have not updated materials, examples or methods to make them more appealing or relevant to the student cohort.

Problem based learning presents many exciting opportunities to embed professional skills into course content. This paper presents a five-level plan that reframes inclusion and diversity around engineering and people. The framework traces the essential elements to both train

engineers to think about people's needs and the development of confident professionals. The approach is founded on discussing excellence and framing progress around this.

INTRODUCTION

While institutional equality, diversity and inclusion (EDI) practices are widespread there are few places where inclusion is threaded into engineering course design, content, and delivery. The speed with which problem-based approaches are being introduced is not matched with an increase in communication and interpersonal teaching of inclusion. For example communication is limited to presentation and writing skills. Few places teach team skills and self awareness This affects students' sense of belonging and can affect achievement and retention. Problem based learning presents exciting opportunities to embed professional skills into course content. While this is happening on many enlightened modules, there is still a resistance to change and failure to see EDI as being relevant to engineering.

The background research for this model has been collated and the many parallel methodologies outlined by Peters (Peters, 2018) in the report *Designing inclusive engineering education*. Knowledge for this manifesto draws on experiences of eight years of work with UCL, piloted with the HE STEM funded Set to Lead project and extended in the development of the Integrated Engineering Programme (IEP) (see for example Peters, Direito, Roach, Tilley, 2019).

RATIONALE

The manifesto provides a framework for conversations around excellence and innovation and fundamentally questions what excellence means in engineering education. Excellence is not just about awarding more first-class degrees, but producing high quality engineers fit for work, solving global and local problems; and empowering and engaging individuals to be their best. It also lays the responsibility for enabling each person to be their best squarely on the shoulders of each student and each tutor.

The much talked about talent and skills gaps mean it is of great importance that each graduate is valued; that each employee at work is valued and able to achieve their potential; and that

drop out rates are minimised. Addressing the achievement gap for undergraduates from socially excluded or black and minority ethnic (BAME) backgrounds means boosting their professional role competence and confidence: increasing their sense of belonging, being valued and being useful.

AIM AND OBJECTIVES

This work has explored and established a framework for reviewing approaches to implementing inclusion in many ways into engineering education and addressing the AHEP guidelines. It is being used in practice at UCL and the Open University. The aim is to consider all ways in which EDI are relevant and to thread into each module where relevant. It provides a systematic approach that leaves it inarguable about why engineering needs to shift.

METHODOLOGICAL APPROACH

A pilot intervention project in 2010-11, funded by the UK Higher Education Funding Council HE STEM programme at UCL, led by the author identified a series of challenges in student group work. A pilot set of scenarios were developed that introduced unconscious bias, stereotypes and self-awareness into engineering-based scenario-based projects with self-selected electronic engineering students. This approach was then extended into first-year electronics and computer science weeklong lab projects, prior to elements being introduced into the UCL IEP. Global good practice was then collated and reviewed through a symposium. Further observations have contributed to the framing of this as a manifesto to aid conversations with engineers around inclusion and 92 elements where EDI are relevant, to consider and structure into conversations and staff training.

THE ENGINEERING EDUCATION PROBLEM: WHY WE NEED A DIFFERENT APPROACH

Alongside pedagogical changes in engineering education (EE) and the focus on active learning approaches, research has highlighted that women are marginalised in engineering project work

(Seron and Silbey, 2015). The experiences of exclusion by women in engineering extend to other minority groups with career defining consequences:

- The degree attainment gap has remained nearly static over the last ten years: In 2012-13, 57.1% of UK-domiciled Black, Asian and minority ethnic (BAME) students received a top degree, compared with 73.2% of White British students – a gap of 16.1%, although this is smaller for STEM subjects (HEFCE, 2015 and Stevenson, 2012).
- Fewer women and BAME engineering graduates choose to work in engineering after graduation than their white male counterparts (McWhinnie and Peters, 2012).

Further, as the student demographic changes ever more rapidly, engineering education must adapt to the needs of evolving students. Staff from Baby Boomer and Generation X need to respond to ways in which the Millennial and Post-millennial generations' mindsets are evolving, based on their exposure to the internet, screen technologies and 24/7 communication (see for example McKinsey, 2018). Underpinning this is their high consumption of information from digital sources, not professors.

The conclusion from the literature and observations is that students are not receiving equality of opportunity in their degrees and unsurprisingly there is an unequal outcome in career destination and salaries. The demand from employers for more diverse employees, driven by both social justice, and also the business imperative (see for example McKinsey, 2015) that businesses with a more diverse workforce can perform by up to 15% better cannot be ignored.

The imperative for addressing EDI within engineering education was laid out by Peters (2018). Implementing this in practice will take time and is not without challenges such as resistance from some teaching staff. The Manifesto now outlines in more detail five levels of actions to create an inclusive engineering working and learning space. In this paper, it is focused on the engineering education environment.

DISCUSSION

This section presents the five stages of actualisation of addressing EDI across engineering in a systematic way. Using Maslow's Hierarchy of Needs as a model, the consideration in engineering is that excellence is a fundamental and of paramount importance to engineers who live and die by the argument of meritocracy.

The level equivalent to self-actualisation is mapped across to innovation. The point at which all of the knowledge, experience and professional practice is drawn together enabling engineers to be creative and demonstrate true awareness and consideration of people within delivering engineering solutions for people's and society's problems and of working with people.

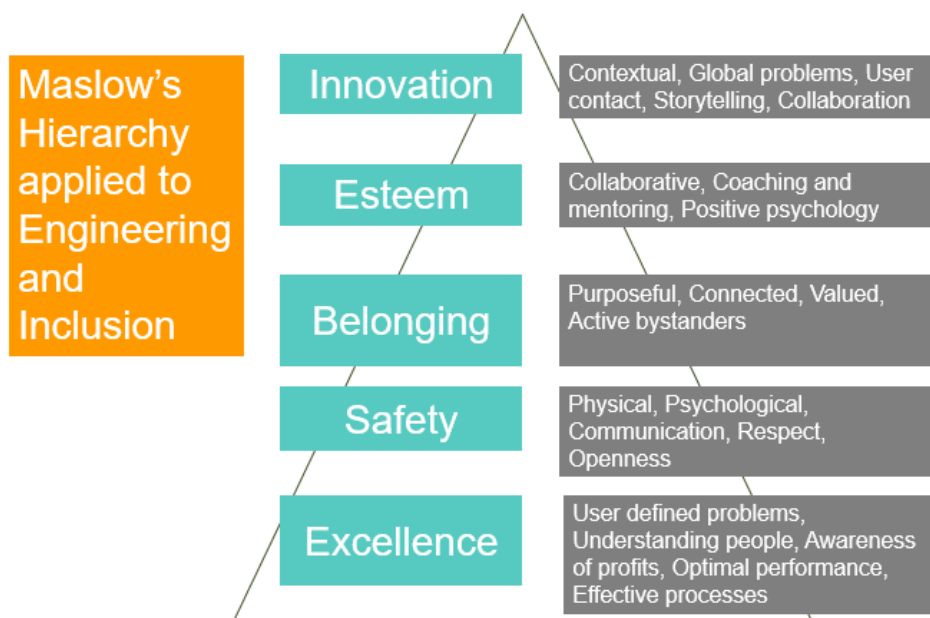


Figure 1: Maslow's Hierarchy of Need Applied to Engineering & Inclusion

- **Excellent teaching, excellent engineers, excellent engineering**

Excellence is what engineers strive for and get measured on: delivering great products and services and in education creating great engineers. An engineering educator, taking time to reflect on their peak performance on engineering and its teaching might consider grades, retention and other metrics to mark their achievements by. But do they, you, ever stop and reflect on peak performance on inclusion and a student's learning experience and whether each students gets the same value form their education? Do academics know who their students are

and how they learn? Do they ever reflect on how users and clients might fit into student projects and explore the challenges that might add to a project or scenario's complexity and also professional insights into sorting out tricky, people based problems? Breaking down engineering education, and asking how or what can be done to improve the learning outcomes, can stimulate thinking and conversations and raise the level of teaching and learning for all.

- **Safety: a safe place to work and learn**

Everyone is entitled to feel safe when working or in a learning environment. To what extent would everyone on your staff or in your student cohort be able to say they feel safe and can be the best version of themselves, without fear of risk, reproach or ridicule?

How do you monitor and adjust practices to achieve a high standard across all that you do? People in a minority group find they have an added cognitive burden; second guessing what is expected, or safe, to contribute to a project or discussion and is acceptable to the cultural norm of a group.

Set standards for the language you use, a professional approach in communications and clarity on styles and phrases. Know what constitutes illegal communication: verbal threats, racism, hatred and innuendo that would be subject to prosecution (under section 1 of the Communications Act [2003]) might be level 1. But level 2 will be when a student or tutor feels they can share who they really are at the start, not the end, of a course.

- **Belonging**

Belonging is a basic human need. Yet in engineering many feel excluded. Engineering is rooted in tradition and a culture that perpetuates the ways of doing things. Unwritten behaviours, jokes and rituals perpetuate a hierarchy, harassment and bullying, often in the name of humour. Traditional, conservative views and values prevent or slow progress and perpetuate the exclusion of people who don't quite fit the mould.

It can be so easy to exclude people unintentionally. Not speaking to female students in class, answering questions or taking contributions from those most eager to contribute. Or just not

noticing some people's contributions. Small, repeated biases that accumulate are evident in everyday acts and comments. Those excluded often don't notice they are excluded until it's too late.

Yet subtle and not so subtle shifts can convey messages that can increase a sense of belonging. See [Why is my curriculum white?](#) as an example of student led change (NUS, 2019)

And while engineers are stereotyped to be logical, rational and un-emotional beings, many are not. Those who aren't, might strive to be and suppress natural tendencies. Those who are need the tools and experience of connecting and checking in with their peers and colleagues. Building bridges, belonging and



engagement. A sense of belonging defines how students interact, can learn about others and get the most from working relationships. Adjusting our everyday language, thinking and behaviours to purposefully include others is a start. Students and staff from non-majority groups will be able to contribute more fully if they are a valued and useful component of the engineering community. These practices develop good habits and mindsets and help ensure our students are fit for employment by employers that value diversity more and more, such as HS2, BAE Systems and National Grid.

- **Esteem and career confidence**

In 2019 there's an esteem and confidence gap for minority and women students in engineering compared to white male students. Multicultural and white male dominated courses can isolate students who are more culturally familiar with a collaborative rather than competitive approach. Introverted or sensitive students lose their engineering confidence. The few become fewer as they leave.

Experience, practice, and formative feedback contribute to personal growth. Teaching students how to ask good questions and introducing coaching styles of communication can contribute to the growth of professional skills. These build a powerful sense of belief and usefulness within students. When coupled with technical competence this leads to confidence that we are a member of the professional engineering community.

- **Innovation**

The final level of the manifesto address innovation. There is much to be learned by considering people and the challenges they face physically, in the environment and society in general. There is also much to be gleaned about the challenges faced from literature other than the engineering and technical journals such as the medical, social science or psychology literature. Creating cross professional respect and communication has never been more important than in twenty first century.

Providing students with opportunities to explore a wider literature, discuss risks, hazards and ethics in a safe space and talk with real users will offer opportunities for innovating and solving problems that have gone unnoticed. Using a model such as that proposed by Leicht-Scholten and Bouffier (2015) to frame every project and response would be a start.

Embedding different users and core professional skills into problem based learning, developing respect for other professionals so that engineers are confident about accessing information in the literature beyond engineering journals, will provide a rich pool of human problems that could be solved with engineering solutions.

Combining technical knowledge with inclusive thinking, behaviours and practices can lead to innovation and new business opportunities. Inclusion-led innovation occurs when engineers connect with and value human differences and explore population groups to inform design thinking. A fertile landscape of cross professional interactions, research, and new conversations will contribute to solving the immense challenges facing society. Engineering and design become innovative, driven by inclusion.

CONCLUSIONS & RECOMMENDATIONS

While many reports and good practice have been produced, the fact that progress has been slow in engineering to adopt and embed inclusion must be because it is often limited to inclusion as considered by protected characteristics rather than in engineering terms of user needs or professional skills. A further reason might be that those teaching have not connected with inclusion beyond a protected characteristic. Creating confidence, therefore, of tutors and lecturers is of paramount importance. Trialling and structuring activities, supporting materials, assessments and reflections must therefore include staff development.

The manifesto approach is about doing better engineering and letting innovation be informed by the needs of people and communities. This is a work in progress. The manifesto aims to facilitate different conversations among engineers to help embed EDI into engineering. And the first is to appeal to the much cited meritocracy and question how far we are from excellence.

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Valuing Diversity and Establishing an Approach to Supporting Excluded Groups

Tudor, Jenna Penlington, Roger

Department of Mechanical & Construction Engineering, Northumbria University,

jenna.tudor@northumbria.ac.uk

KEY WORDS: Diversity, Inclusion, Inequality, Career development,

SUMMARY

Minority students and minority employees in Higher Engineering Education experience inequality. For academic staff these inequalities impact their personal development and career progression. To continue to grow and for engineering education to thrive as a professional discipline we must encourage diversity within both the student and staff populations. This paper cautions against a simple notion of diversity, rather a truly diverse culture within engineering is needed, one in which there is diversity of opportunity, diversity of thought and diversity of experience. To enable a more inclusive environment to flourish we must understand the scale of the inequalities which exist. However, this paper demonstrates that there are significant limitations to the current diversity data within the UK which leaves room for under-reporting and over-generalising. In addition, there are cultural challenges which give further likelihood to non-disclosure and lack of self-reporting.

This paper proposes that further research is needed into the true lack of diversity within engineering and describes one example of a 'thought experiment' conducted by the researchers to start unpacking the data and highlighting the scale of the issue.

INTRODUCTION

Minority students and minority employees in HE engineering education experience inequality; they report “lower satisfaction, experience exclusion and under achieve” (Royal Academy of Engineering, 2018a). Academic staff from underrepresented groups face barriers to personal development and career progression. It is a firmly held belief of the authors that overcoming barriers, actual and perceived, for academics is a necessary precursor of an environment which will enable a fully diverse student body to flourish.

These barriers to inclusion and diversity are present at a time when engineering employers from across the UK are highlighting their need for more engineers with the human capital (including diversity of innovation and creativity skills) to address global challenges (Bontis, 2001). To meet the industry demand we must encourage people from all backgrounds and with a variety of diverse experiences into the discipline (Royal Academy of Engineering, 2018b). Diversity must therefore be an expected outcome for engineering education (Appelhans et al., 2019).

Role model research suggests that exposure to successful ingroup (vs. outgroup) members enhances motivation and aspirations among negatively stereotyped individuals (Dennehy and Dasgupta, 2017). There is a need to develop students with “diverse and innovative mindsets in engineering education” thus Godwin (2017) warns against the process of enculturating students into engineering through an engineering curriculum which fails to promote diversity and instead creates homogeneity in students’ approaches to problems, ways of thinking, and their attitudes.

LITERATURE REVIEW

Having a diverse workforce can support access and participation of students (U.S. Department of Education, 2016). Enabling diverse perspectives and lived experiences to be shared with students provides them with role models and mentors, thereby helping to prepare them for a future in a diverse world (Taylor, et al., 2010).

Many current diversity initiatives are focussed on addressing the “leaky pipeline” model without policy or culture change, where diverse students are recruited to STEM fields and then slowly leak out at various stages in their education and subsequent careers (Appelhans et al., 2019). Mirza (2006) recognises the need for HE institutions to treat matters of culture, equality and diversity as core structural issues which must go beyond initiatives which simply aim to add members of minority groups to the workforce. HE must instead look to change policies and cultures (Sharp et al., 2012).

The current data highlights significant inequalities and a lack of diversity across academic staff (HESA, 2018). HEIs have a statutory obligation to submit data to the Higher Education Statistical Agency (HESA) including data on staff and students’ sex, race/ethnicity, disability and age as part of their annual returns, and from 2017/18 this also included religion or belief for the student record. Institutions can return voluntary data on religion or belief for the staff record, sexual orientation and gender identity for staff and students, and on parental leave for staff. Data on the protected characteristics of marriage and civil partnership are not collected (Advance HE, 2019a). Given that some elements of the data submission to HESA are voluntary, for the purposes of monitoring and action this situation of partial data collection is a significant limitation and consideration must be given to how data is collected, processed/aggregated and reported. For example, not all institutions report in all categories, numbers may be rounded to protect small populations from identification of individuals and where information is not provided it may be included in the ‘not declared’ category suppressing the actual value.

Brewster et al., (2017) recommend considering intersectionality when looking at data, where gender is considered together with other forms of difference and inequality an individual may experience such as their ethnicity or sexual identity (Klein, 2016). Intersectionality data is starting to become included within reporting (Advance HE, 2019b and Equality Challenge Unit, 2017) yet incomplete data returns mean that qualitative approaches are incorporated if context specific monitoring is sought and the low numbers of those at the intersections of multiple underrepresented categories are small. This can result in the importance of these individuals being dismissed (Godwin, 2017).

Rather than being its own end, demographic diversity can act as a useful and as a visible indicator of progression toward diversity of thinking (Bourke & Dillon, 2018). Moving beyond the

reporting of visible and non-visible socially constructed identities offers potential for increasing diversity with engineering education. Phillips and Loyd (2006) recognised that deep-level constructs of diversity (e.g., attitudes, opinions, information, and values) exist alongside surface-level categories. They reflect that much of the previous research on diversity has assumed that “surface-level characteristics are a proxy for or are congruent with deep-level characteristics” however they warn that “social category diversity may not always reflect other types of diversity.” We consider this to include situations where academics may, due to a dominance of their own learning style, confuse individual student’s preferred approach to learning with an indicator of their ability. Effectively failing to recognise diversity of thought and thinking, resulting in a situation where like types succeed and others are expected to conform to that type regardless of how much anxiety this causes. Studies employing the Myers-Briggs Type Indicator (MBTI) within engineering, such as Yokomoto and Ware (1999), have not generally considered the MBTI staff at the same time as that of the students. Lester et al., (2003) reports that 73% of the students were categorised as ‘Sensing’ (which is approximately the same as the general population) yet for the staff group the figure was 30% with 70% being categorised as having a preference for ‘Intuition’.

THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

The authors of this paper have a longstanding interest in the contribution of faculty identity, attributes and abilities upon engineering education and are involved in a cross institutional project in the North of England funded under the EPSRC Inclusion Matters scheme which seeks to establish best practice in support for underrepresented groups within engineering and the physical sciences (see project website for further information northernpowerinclusion.org). Being engaged in such a project necessitates further thought upon the nature of what are the underrepresented groups represented within engineering educators and specifically how we define underrepresented groups.

DESCRIPTION OF INTERVENTION

The project discussed in this paper is a work in progress. The researchers are conducting a series of 'thought experiments' (Galili, 2009) as preparation for a more detailed study as such experiments may be based upon making judgements from poor or incomplete data so long as outcomes are viewed as probabilistic. This approach is considered as particularly suitable in enabling an initial consideration of non-visible conditions and their relationship with disciplinary performance as well as custom and practice.

So how does a thought experiment allow a different perspective to be explored? Having established that diversity of thinking brings value how may diversity be represented by ways of thinking? One aspect to consider is cognitive or neurodiversity, non-visible differences in ability from neuro-typical to neuro-divergent which includes a range of conditions amongst which are varying degrees of an Autism Spectrum Condition (ASC), attention deficit disorders, and dyslexia. Such conditions are known to have association with ways of thinking employed by engineers. Is it possible that engineers collaborating around the World are actually bringing fewer diverse ideas to the table than expected? UK Statistics (DWP & DHSC, 2017) estimate that 17% of the working age population declare a disability yet only 2.9% of engineering academic staff declare a disability (Advance HE, 2019b). Do these statistics signify that higher education is not an equitable employer or that it has a reporting problem?

Figure 1, Example of a diversity Thought Experiment.

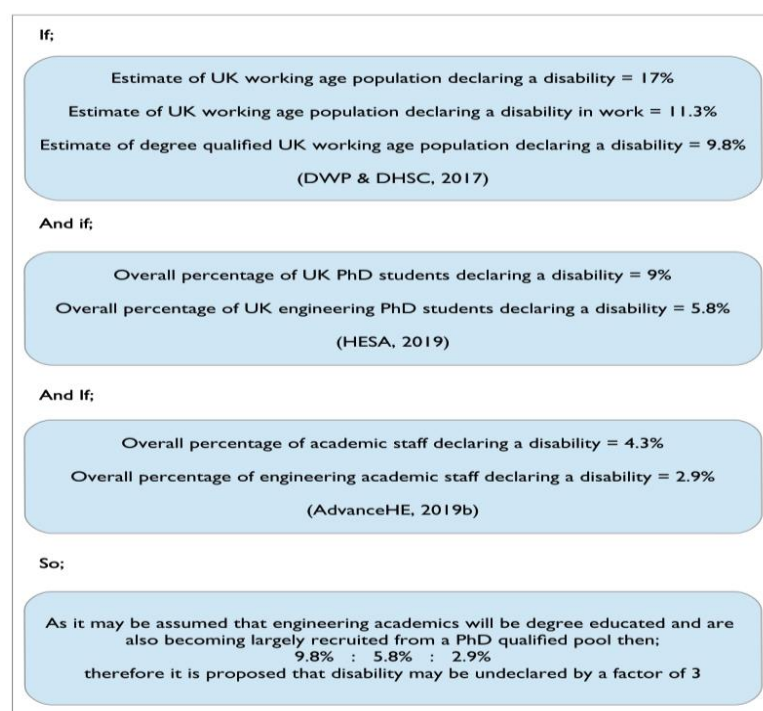
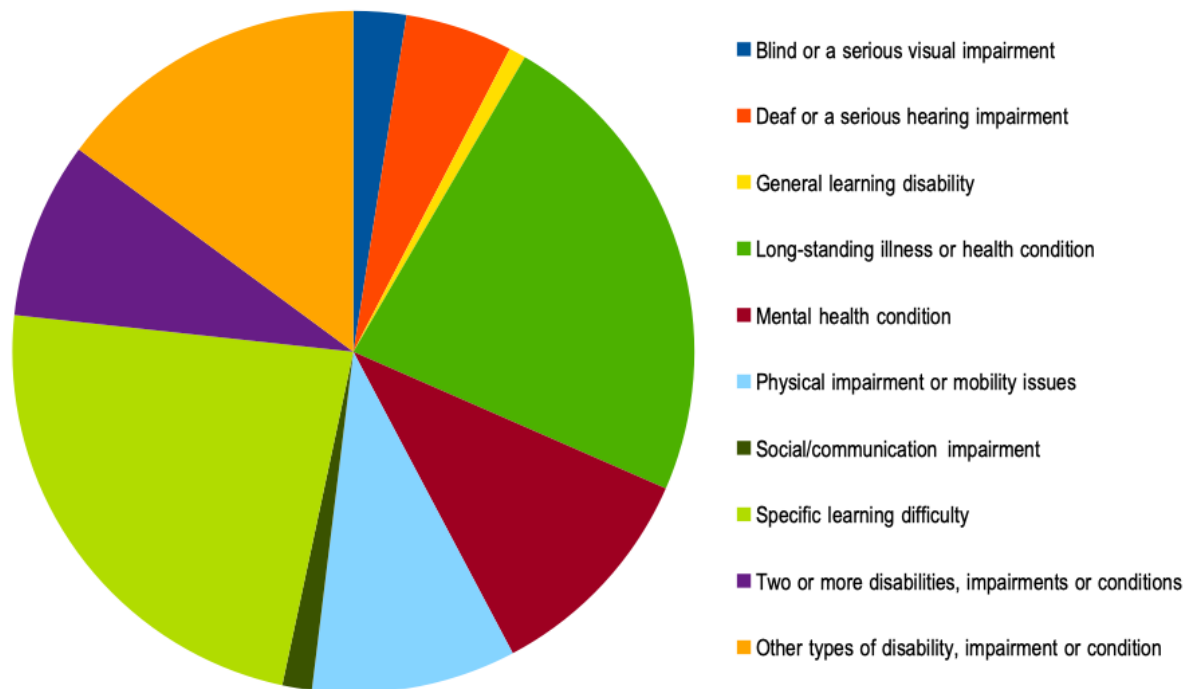


Figure 2 Breakdown of academic staff declaring a disability by type 2017/18 (HESA, 2018)



It can be seen that Long-standing illness or health condition (23.2%) and Specific learning difficulty (23.4%) which is now classified as “A specific learning difficulty such as dyslexia, dyspraxia or AD(H)D” by Advance HE are the most widely reported disabilities. It is noted that “Social/communication impairment” (1.4%), which includes the Autism Spectrum Conditions (ASC), may be a little higher than predictions for the general population (variously reported as being around 1%).

This is particularly interesting as links between engineering and autism have been established such as 12.5% of fathers of children with autism were engineers compared to around 5% for other groups (Wheelwright & Baron-Cohen, 2001). They also report that these were professionally qualified engineers rather than skilled or semi-skilled manual working engineers. A large-scale study (n = 450394) of a self-report instrument for adults, the Autism-Spectrum Quotient (AQ), was used to quantify autistic traits (Ruzich et. al. 2015) within the audience of a TV programme found that both males and those in STEM occupations scored more highly than both females and those in non-STEM occupations.

EVALUATION OF INTERVENTION / PRACTICE

Current reporting of diversity tends to start from a position of 'otherness' (Bolt & Penketh, 2017) where reporting equates to problem characterisation and deviation from some form of notion of normal. A typical situation would be where a diagnosis of a condition may signify for some a disability yet for others may only be seen as a difference in ability. An example of this would be the differences in cognitive profile of a dyslexic engineer from that of a neuro-typical profile, here positive attributes of heightened ability in visualisation and logical reasoning may exist along-side challenges with spelling and reading.

The notion of 'otherness' is reinforced by the assumption that data not collected or not offered-up is rolled into the convenient 'normal' group, consigning under-representation to appear as an even smaller minority group rather than is the known situation. Not only does this mask those undiagnosed yet also potentially disadvantaged, but also those who do not feel able to declare for fear of a negative impact upon their daily or future career.

What stands out when a deeper look is taken at diversity within engineering education is the potential that we are not aware of the degree to which we are bringing together different ways of thinking or fostering diverse mindsets. There are many descriptions of engineering mindsets which focus on skills, knowledge and processes used by engineers but which fail to place the engineer at the heart of the system or give value to the individual nature of the engineer's abilities (Glover & Kelly, 1987, Madhavan, 2015). Does engineering education therefore have a further problem beyond the issues linked to current diversity reporting, do we also fail to consider the diversity of thinking across our staff? Whilst we work towards diversity, and do have staff with diverse cultural and educational formative experiences, does a lack of diversity in ways of thinking lead to a narrowly focussed 'group think'? Organisational units regardless of culture, age, gender may currently be constrained in their effectiveness by discipline-based practices and norms, particularly where values and measures of success are very restricted in range, for example by publication metrics and grant winning.

DISCUSSION

The authors' involvement in the first round of Inclusion Matters projects from EPSRC (<https://epsrc.ukri.org/funding/edi-at-epsrc/inclusion-matters/>) has further highlighted gaps in current practice, and recognise that as engineering education professionals we need to do more, but fundamentally we also need to understand more.

The need to diversify staff, students for the Engineering Profession has been recognised by some but inadequately by others (EDAP, 2015). As engineering educators we must reflect on the cultural/structural issues which may actively discourage individuals from self-reporting, allowing us to challenge the acceptance of missing data and take on the real challenge of enabling thorough and meaningful analysis.

We need to question how we can learn the stories behind the data. Deeper thinking about diversity, not taking it at face value that we are making progress towards diversity based on numbers. We need to consider beyond the traditional characteristics and incorporate 'ways of thinking' as a more comprehensive measure of diversity

The issues are evidence and the data show a lack of diversity but we have demonstrated that there is a very high likelihood that the real situation is very different to that demonstrated by the current data. And we must question the culture in which the data is defined and collected and the inclusivity and opportunities for equality within the discipline. It is logical that engineering education leads on this as the main influencer on the formation of future engineers.

CONCLUSIONS & RECOMMENDATIONS

As a profession we need to do much more to understand our workforce, to understand the current representation of diversity and do more to understand challenges to equality and inclusivity. We need to move on from a numbers based diversity approach and consider a culture which provides equality of opportunity for all to the benefit of the profession.

To rise to the complex challenge of preparing future engineering professionals a new look is needed at what we already know, reflecting on and redefining 'what matters' and moving away from 'group think'. There is an opportunity for change to ensure engineering education appreciates diversity and develops graduates who are in demand by the profession.

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Students Exploring Power and Privilege in Engineering Design for Sustainable Community Development

Xavier, Patricia^a Orbaek White, Gabrielle^a Groves, Catherine^a

^a Swansea University, UK

p.a.xavier@swansea.ac.uk

KEY WORDS: Critical Reflection, Positionality, Post-colonialism, Sustainable Development, Hybrid-learning

ABSTRACT

Engineering students commonly struggle to articulate the relevance of the social pillar of sustainable development to their profession. Partially in response to this, the MSc in Sustainable Engineering Management for International Development at Swansea University was developed, bringing together social science and engineering students to conduct fieldwork with partners in Sierra Leone and Zambia. The aim is the development of transdisciplinary practitioners who can apply engineering solutions while being sensitive to social context.

One particular practice from critical management studies has emerged as a potentially powerful applied methodology within the engineering context to address the social pillar of sustainability. Students and some staff are encouraged to engage in critical reflection following Reynolds (1998), selected as a framework because it encourages the questioning of implicit assumptions and exploration of inequalities in power in the social context. Critical reflection of this nature appears to help the students interrogate inequalities in power they encounter (e.g. racial and colonial) to explore whether they are reproducing or resisting these in their project delivery. For example, students considered whether they were marginalising rather than empowering their in-country partners, despite their well-intentioned actions. As well as critically examining themselves during project work, the students also started to deconstruct the rationale underlying the MSc, engaging in discussions around complicity with neo-colonialism.

INTRODUCTION

Evidence indicates that engineering students struggle to conceptualise the three-pillar model of sustainability (environmental, social and economic considerations). A common misconception is that sustainability relates to environment alone (Ashford, 2004). If students do consider the social dimension, they may recognise their general role in 'improving' society and their responsibility to health and safety, while not being as concerned about the broader social impacts of their work (Rulifson and Bielefeldt, 2018). Curricula may be training the social out of engineering students: Cech (2014) showed that public welfare beliefs amongst engineering students decrease over the course of their degrees.

Attempts exist to reframe the engineering curriculum, more firmly emphasising the social dimension of sustainability. Bowen's (2009) 'aspirational engineering ethics' seeks engineering education that emphasises engineers' responsibility to contribute to human wellbeing. Conlon *et al.* (2018) call for a 'macro-focus' to engineering ethics that 'should involve interrogating both the goals of the profession and the social context in which engineers work' (Conlon *et al.*, 2018, p.7). Jamison *et al.*, (2014) propose 'hybrid-learning', an integrative educational approach where scientific knowledge and practical skill is combined with social and cultural understanding.

International Service-Learning (ISL) educational programs incorporate fieldwork to enhance experiential learning. A hybrid-learning approach to ISL encourages students to appreciate multiple subjective viewpoints and learn the language of the community in question. This can develop an 'insider' perspective (Brown and Duguid, 1991), drawing attention towards the interaction of diverse identities, as well as the underlying power relations found there (Lave and Wenger, 1991).

At Swansea University, multi-disciplinary faculty from engineering, management and humanities launched a new MSc in Sustainable Engineering Management for International Development (SEM4ID) in 2017. The course fuses hybrid-learning with ISL projects, giving students an opportunity to develop skills in engineering design while being challenged to 'listen and recognise value in the perspectives of others' within the context of communities' histories, voices, concerns, conflicts, knowledges and desires.' (Lucena and Schneider, 2008, pg.255) The

course co-educates students of social science and engineering to encourage development of shared language and frames of reference. Engineering projects developed in 18/19 include: a solar-powered rig to convert chicken manure to fertilizer and a solar-powered timber-seasoning kiln, both located in Newton, Sierra Leone, and an aquaponics system within a school in Siavonga, Zambia. Students participate in two periods of fieldwork. For more on the structure and delivery, including modules and overall teaching, learning and assessment strategy, see Xavier and Holness (2019).

Due to the political undertones of the fieldwork location, students were directed to explore the impact of power and privilege on engineering design in a non-Western context. Coming from a UK-based institution, they were forced to recognize that, regardless of their country of origin, they were perceived as an extension of a post-colonial institution. This has pushed students to grapple with legacies of racism and colonialism during their engineering design, recognizing that the history of the UK slave trade and continued economic marginalisation are factors that they are inevitably entangled within.

Students were asked to consider these issues through a series of critically reflective essays. This teaching, learning and assessment strategy emphasized Reynolds' (1998) accessible yet rigorous framework for critical reflection. Critical reflection, according to Reynolds, is distinctive from other forms of reflection in its commitment to (i) questioning assumptions and raising questions that are moral as well as technical in nature; (ii) bringing processes of power and ideology to the fore; (iii) having a social rather than individual perspective; and, (iv) being concerned with emancipation.

RATIONALE

Content from critical reflections from the students indicate that students are identifying inequalities in power and questioning the implications for their professional responsibility towards their stakeholders. In response, teaching, learning and assessment practices around critical reflection have deepened each year as faculty learn more from this practice.

This research project seeks to understand the themes emerging from student reflections. It also attempts to establish if and how critical reflection can be used to strengthen student understanding of how their socially constructed individual worldview (positionality) impacts on engineering decision making.

METHODOLOGICAL APPROACH

This paper is part of a larger ongoing thematic analysis of students' critical reflection journals from 2017-2019. Critical reflections were collected at two points in the year, a 2000-word assignment written immediately after their 1st fieldwork assignment, and a second 4000-word assignment at the end of their period of study.

The study was approved by the College Ethics Committee and all students consented to participate in this research.

KEY FINDINGS

Preliminary data from student reflections reveal varying depths of criticality of reflection. Emergent themes include: power differentials, which students attributed to race and neo-coloniality; challenges of working across cultural difference, and; moral and ethical questions about participation in development, as part of their course and more generally.

Several students explored how their own physical and cultural identities shaped their experience:

“Just as I had related to the locals because of the colour of my skin, the undergraduates might have found it difficult to do so because of the same exact reason thus creating a divide between “us” and “them”” – Student 1, BAME male (engineer).

“...because of the colour of my skin... regardless of my professional expertise... or lack thereof, I am elevated on a pedestal and I can get to the front of the queue” Student 2, white male (social scientist), reflecting on achieving a high-profile ministry visit.

A common theme was the reluctance of the Sierra Leonean and Zambian partners to criticise the sometimes naïve actions of the students:

“This paternalistic behaviour... is also what makes [the worker] automatically become a yes man and make statements such as ‘na una for go school and bring the idea cam so me no for get contribution pan the idea’. Essentially saying despite being very experienced in his field, he is unable to make suggestions because we are university educated and therefore in a better position to make valid suggestions.” Student 3, BAME female (engineer).

Several students reflected on and critiqued their needs assessment and project development processes:

“We did not design our stakeholders’ engagement to get the best from the lowly ranked in the community and we also assembled only stakeholders with interest in the classroom block and was not surprising they unanimously supported it.” Student 4, BAME male student (engineer).

“Taking a step back allowed me to see that perhaps we were not empowering workers in the way we believed we were. Our perceptions were so blurred by our [white saviour complex] and belief of doing good, we failed to see us taking charge of our projects removed a level of power from those in Sierra Leone, with this power ultimately being the driving force behind their empowerment” Student 5, white female (social scientist)

Colonialism emerged as a theme of relevance:

“Aren’t many of the problems of Sierra Leone rooted in its British colonial past? Surely, we should come to this country on our hands and knees, begging for forgiveness for our past crimes, rather than with a superior, saviour-type attitude, which I recognised a little in myself – but observed more outwardly in some of my colleagues.” Student 6, BAME male (engineer) from the UK.

“Why have I enjoyed the “quality” of being born in another part of Europe, a characteristic which has nothing to do with my choices, achievements or humanity? In that particular moment, I was proud that I am not the “colonizer”. But neither my British colleagues are, directly. Why would they deserve such a treatment when they do not agree with what their ancestors did?” Student 7, white female student (engineer) from Romania reflecting on being more warmly received as a result of not coming from the UK.

Conflict about participating in the programme is also a recurrent theme:

“At this stage, the hypocrisy really set in because did that make me the “black saviour”? Was I really using development and these people as a leg-up to the next stage of my own development...? Everyone says I am doing good work because I had spent time building filters for a village in Africa, but to who’s gain?” Student 8, BAME male (engineer)

“We did not want Sierra Leone to be our “playground”, ‘a liberated space in which the usual rules do not apply’ (Cole, 2012) . Sierra Leone does not need more “white saviours”, but people that “start listening before speaking, learning before acting and partnering instead of leading”” (NWS, 2019). Student 7, white female student (engineer)

DISCUSSION

It has been a turbulent process for both staff and students who are becoming aware, sometimes for the first time, how inequalities in power manifest in their relationships with others. In some cases, the process of reflecting on the role of engineering in this context is transformative. There is an apparent transition that many of the students undergo, from setting out to “*make a difference*” with a “*saviour-like attitude*”, students appear to commonly experience a crisis, e.g. “*the hypocrisy set in.*” Some students progress to articulating a more considered approach, e.g. citing Cole (2019) “*listening before speaking, learning before acting and partnering instead of leading*”.

Sustainable engineering design calls for technical content to be socially contextualised (Bowen, 2009; Jamison *et al.*, 2014; Conlon *et al.*, 2018), and acknowledges that we both affect and are affected by the world. Bowen, (2014) suggests engineers adopt approaches from African ethics: ‘Ubuntu’, from the Nguni language conveys the sense that all is relational – ‘a person is a person through other persons’ (Bowen 2014). The critically reflective accounts provided a unique window to study ‘talk in use’ (Lawless, 2008, pg.120) as a means of understanding how the students were becoming ‘insiders’ (ibid) creating and negotiating representations of their identity and their view of the world they found themselves participating in.

Of note to educators, once criticality was unleashed, it resisted direction. Students did not refrain from critiquing the course and teaching faculty for what was perceived as propagation of the Global North/South, helper/helped paradigm that may be perpetuating the narrative of a passive Africa reliant on intervention from the West for its development. For examples, references to the course using project locations as ‘our “playground”’, and considering ‘*who’s to gain?*’ through their project work.

Of concern is the strain that engineering educators have experienced in joining the students on their critical journey. Ahern *et al.* (2012) notes that in technical, content-driven disciplines, critical thinking is not taught explicitly, and engineering academics struggle to articulate what it means. Developing the skills to facilitate discussions of power and privilege in engineering design requires confronting the limits of the epistemology underlying engineering, rooted as it is in a positivist worldview. Moving towards the unfamiliar culture of a more interpretive educational

paradigm is a challenge, but arguably one that is unavoidable if engineering is to meet the challenge of sustainable development.

CONCLUSIONS & RECOMMENDATIONS

Critical reflection was introduced to aid exploration of positionality and students' relations to inequalities of power and so interrogate the social dimension of sustainability.

Critically reflective practice was also seen to destabilise the traditional educator/educated hierarchy. As educators, we do not have all the answers to the modern age, the climate crisis being one indicator that new approaches are needed. Equipping our students with the ability to critique and reframe the profession within sustainable practices could help rehabilitate engineering to be fit for the changing world.

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Open-Ended Project Work: Sharpening Students' Skills

Jemmett, Philip, N., Burton, Diane · Cannon, Emily,
Harris, Laura, Diebolt, Marie & Low, Margaret

University of Warwick, U.K.

Philip.Jemmett@warwick.ac.uk

KEY WORDS: Widening Participation, Project-Based, Group Work, Transferrable Skills, Residential

SUMMARY

WMG delivered and supported a group project for the Experience Warwick Summer School run by the Warwick Outreach and Widening Participation team. Each group was given the same set of equipment and minimal guidance towards what to create: they were provided with challenge cards to spark imagination but, after the first day, these cards were hardly used with students instead chasing their own inspiration. Participants were supported by University of Warwick student ambassadors and mentors from the WMG Graduate Programme and WMG research staff during the project. Ambassadors coached the students on team work while the WMG mentor helped with technical aspects and realising their imaginative ideas. A showcase, attended by teachers and families, included a smart city model, a radio-based game and several remote-controlled or line-following vehicles.

Two main outcomes from student self-reflections were discernible:

1. *The students self-reported an increase in engineering-related skills.*
2. *Students became more aware of current engineering research areas and the role that research has in shaping modern society.*

This was a successful pilot of a project-based programme of activities for year 10 students. In the summer of 2020 this project will be repeated for a new cohort of year 10 students but also expanded into a full, engineering-based work experience programme.

INTRODUCTION:

An outsider's perception of engineering may be different to reality. Students often have little idea of what an engineer is and no appreciation for the diversity of roles engineers can have (Royal Academy of Engineering, 2016). It is necessary to get students out of classrooms, away from textbooks, and to open their eyes to the many images of an engineer.

Having the opportunity to 'tinker' and explore materials outside of the classroom is an obvious point at which young people build their own engineering identity (Royal Academy of Engineering, 2018). This is obviously a challenge for students in areas of deprivation who might not be able to afford to buy kits and tools to experiment. This is before one considers the extra time burden on such students who might need to take an active role in care and labour around the home with parents potentially having additional or shift-based work.

We aimed to give students from widening participation backgrounds an opportunity to build an '*engineering identity*' by working with practical examples and showing their creations to their families. Only one in ten engineering undergraduate students in the UK are from the lowest quintile and only 24% of engineers are described as 'from a disadvantaged background' (Engineering UK, 2018). These underwhelming numbers clearly demonstrate the necessity of providing additional support to students from widening participation backgrounds: both to widen the talent pool available to recruiters but also to ensure that all young people have equivalent possibilities and opportunities, regardless of their geographical location.

LITERATURE REVIEW

Improving diversity in engineering should be a priority (House of Lords, 2012). Thankfully, an evidence base of 'what works' is growing (e.g. [Freeman, 2014]). Potential barriers have been highlighted such as a lack of 'science capital' (Archer 2015). Science capital can be built by access to science kits or experiments at home, conversations between adults and young people about STEM subjects and careers, or visiting a place of learning such as a university; all of these have proven links to aspiration and attainment (Archer 2012, 2015). Additionally, increasing science capital can lead to a snowball effect, wherein more capital can be accrued (Dawson 2014a and 2014b), which will only increase young people's ability and confidence within STEM subjects.

An additional barrier is the range of skills that are needed for engineering jobs (Nair 2009). Soft skills are often built through extra-curricular exercises which may feature advantaged students more prevalently. This creates an additional bias against students from disadvantaged areas and perhaps creates another 'leak in the pipeline'.

Further, once students are in an engineering job, Kumar *et al.* (2007) showed progression into senior positions is more likely if they were taught with innovative pedagogy, e.g. problem based learning. This is a key reminder that widening participation does not end at the university application stage: students should be supported throughout their careers to fix the 'leaky pipeline' and, to borrow a phrase from Dasgupta and Stout, "STEM the tide" (2014).

This activity was designed to utilise student voice and provide them with agency over their own work, similar to a previous project the author was involved with (YES for STEM, NERUPI Case Study, 2018) which used mentors to support students designing an outreach activity. It is expected that control over the direction of the project will enable the student to reflect upon their personal impact and, through creating something unique, they can envisage themselves as engineers.

CONTEXT: THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

To provide students an experience of engineering where they were free to explore in their own style at their own pace, we provided the equipment and tools and then encouraged the students to experiment with what they were interested in. Guidance was provided *via* a set of challenge cards (Figure 1) as a starting point. Mentors were provided to each group to assist with content points but were specifically trained to allow the students to explore without boundaries.

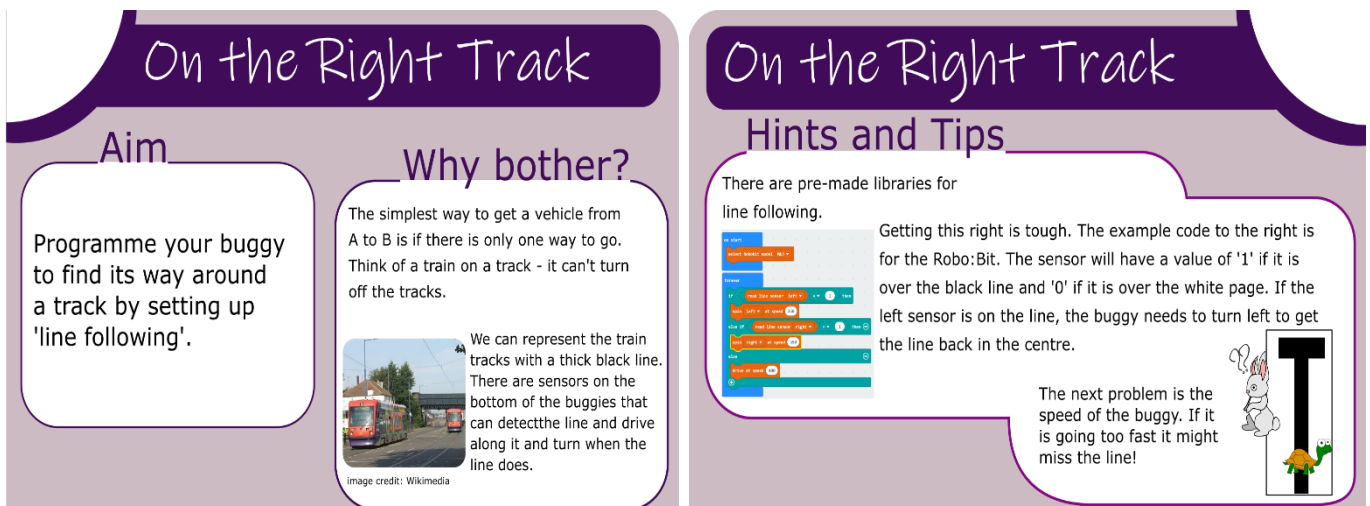


Figure 1: An example of one of the six challenge cards provided to the students.

DESCRIPTION OF INTERVENTION / PRACTICE

Thirty-nine Year 10 students were recruited by the Widening Participation team at the University of Warwick. These students were given accommodation on campus for three nights. The breakdown of Widening Participation indicators within the group is given in Table 1. POLAR (**P**articipation **O**f **L**ocal **A**reas) is a measure of the progression rate of a geographical area into Higher Education (HE). Students who live within the lowest two quintiles (Q1 and Q2) are less likely than average to progress into HE. None of the recruited students had parents who had been through HE.

Table 1: Widening Participation indicators in the cohort

Indicator	Number of students	% of group
POLAR4 Q1 or 2	25	64%
First generation in HE	39	100%
Female	24	62%

In total the students had 6 hours over three days to work on their projects. Seven groups of six students were all provided the same starting materials. These were laid out on tables in an identical way. An undergraduate student ambassador was with the group at all times and was responsible for all pastoral matters. Additionally a member of staff from WMG's graduate

engineering scheme was placed within each group to assist with the development of the project; though they were instructed not to suggest what the students should work on.

On the first day the students were given an introduction to the work that WMG does and given a task to look for examples of engineering within pictures of the local area. On the second and third days of the project students worked on their projects. The event culminated in a showcase of the students' creations, attended by families and teachers. Examples of their work are shown in Figure 2.



Figure 2: Examples of some of the students' creations

EVALUATION OF INTERVENTION / PRACTICE

A multi-faceted, though light touch, approach to evaluation was taken throughout this event. To gauge participants' subject knowledge and awareness of engineering, they were shown photos of local areas and asked to list the examples of engineering they could see. This was to encourage the students to ground any knowledge they acquired during the summer school in the real world and be more aware of how engineering affects their environment. No in-depth analysis of their responses has been undertaken: the activity was influenced by student ambassadors. However, it is important to note that participants were encouraged from the beginning to reflect on the context of their activities.

Students were encouraged at several points to make notes on their group flipchart of any skills they felt that they had practised and any new things they had learned. This was intended to be a self-reflective task for the students to help them realise how they had grown into the role of engineers and reinforce an engineering identity within them. This approach was taken to avoid formalising our intentions to improve the students' soft skills, given that students can be resistant towards soft skill courses (Pulko, 2003). Photographs of these flipcharts are available.

Recurring themes noted by the students were grouped and their frequencies counted (Figure 3). The data were reported on a group-by-group basis so these responses do reflect the full 42 students but are counted to a maximum of seven.

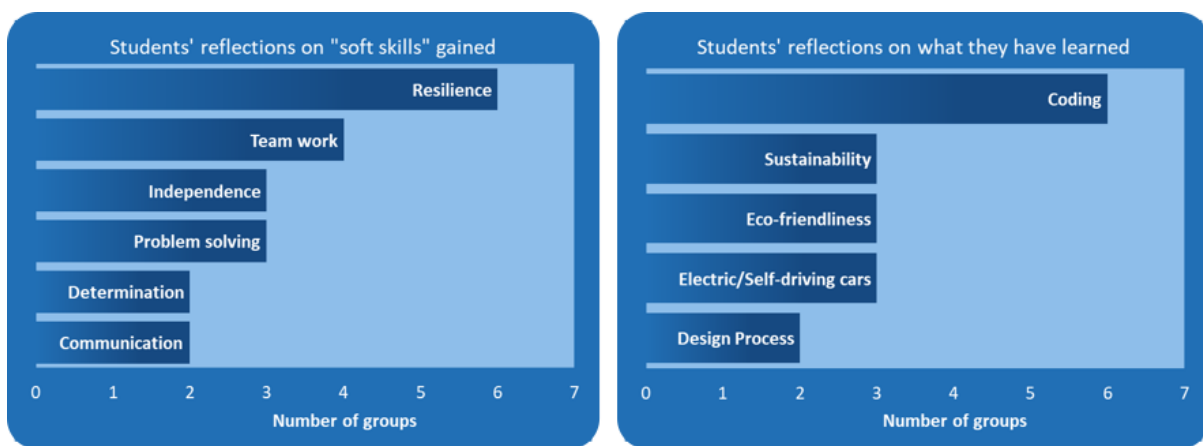


Figure 3: Self-reported reflections by the students on the outcomes of the project. Answers gathered into groups based on the reported frequency. Left: students asked what skills they had learned. Right: students asked what subject areas they learned about.

- **Outcome 1: Young People Self-Report an Increase in Engineering-Related Skills.**

Self-reported data demonstrate that the experience encouraged students to think about resilience and team work. These skills are crucial to aspiring engineers (Royal Academy of Engineering, 2014), so their presence in these self-reported data suggest the balance of content-heavy activities with time to internalise the process was effective.

- **Outcome 2: Increased Awareness of Current Engineering Research Areas.**

These responses demonstrate that the students have seen the context for WMG's research. Additionally, the process of designing and improving a product and advanced computer-related skills, such as coding, are crucial skills to modern engineers. These students were from the local area and as such they should feel some ownership over the local research efforts. We hope that the students will see a news item or an autonomous vehicle in the future and relate that item to their own engineering identity.

The student cohort has also been tracked following the event with the intention of inviting them back to the department for an engineering work experience programme. Subsequently the students have provided quotes reflecting on the event:

"No coding experience. Challenging trying to get it to work. Learnt how to do it. I feel like I could go home and code stuff." (Student)

"Challenging bit, robots... (Student)

Likewise, families and teachers appreciated the opportunity to attend the showcase event:

"...thanks so much for giving my [child] such a fantastic experience. [They have] talked about it constantly since [they] got home and it has made [them] more determined than ever to get the grades [they need] to get to University" (Parent)

"...how lovely it was to see the students 'graduate' ...afterwards, one of my student was explaining [their] robotic engineering and showed such determination to get the task completed." (Teacher)

DISCUSSION

Having groups of six students meant that the groups could split and work on two things at once successfully. We feel that this group size is ideal and we will use it in all future iterations of the project.

Family and teacher responses that students have been talking about their project work implies that providing an opportunity for parents, guardians and teachers to see the creations of the students will facilitate conversations about STEM outside of the classroom in the future. This is one of the factors that increases science capital and therefore may increase the likelihood of these students considering STEM careers.

CONCLUSIONS & RECOMMENDATIONS

This was a successful pilot of a project-based programme of activities for year 10 students. Key findings include:

- A group size of six works well for these projects,
- Having the opportunity for parents, guardians and teachers to see the work the students have created is well-received by those families,
- Students engage when they are able to focus on an aspect of a wider problem that interests them.

A repeat of this event is scheduled for 2020, where a more formal evaluation procedure will be used throughout the event. It will follow the same structure as the data collection utilised here (*i.e.* students will be asked to reflect on the skills and content they have learned and the context that their new skills and knowledge will be useful in) but with a few modifications to account for likely sources of bias, e.g. student ambassadors suggesting answers in the ‘Where is Engineering?’ ice-breaker/knowledge test activity.

Additionally the approach will be expanded further into a full work experience programme, open to the same cohort of students featured in this paper, based around open-ended, mentor-supported group project work with links to active research at WMG.

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Professional Body Accreditation and the Quality Assurance of Engineering Education Programmes

Kyne, Maria

Limerick Institute of Technology

Maria.Kyne@lit.ie

KEY WORDS Engineering Education, Accreditation, Programmatic Review

ABSTRACT

All programmes of study in Institutes of Technology in Ireland are subjected to internal programmatic review in five yearly cycles to ensure that the programmes meet the quality assurance standards and are fit for purpose. In addition engineering and construction programmes undergo voluntary external accreditation by their respective professional bodies. Both the programmatic review and accreditation processes have evolved and diverged over time. The focus of the accreditation process has changed significantly in the last ten years towards the measurement of student achievement of learning outcomes. According to the research literature, this new accreditation process focus has gained worldwide acceptance and is a driving force for ensuring the quality of engineering education programmes. If the internal quality assurance programmatic review process can be enhanced by using the outcomes evidence based methodology of the accreditation process, these two quality assurance processes may be brought into closer alignment. It may then be possible to have a single five yearly quality assurance of engineering education programmes which would be accepted for accreditation by the professional bodies. Significant consultation has taken place with the gatekeepers of these processes. The research is designed to gain insights from experts using an adopted Delphi technique methodology to collect data and the constructivist grounded theory to support the analysis of the data. Implications for quality assurance of engineering education will be discussed.

INTRODUCTION

The fundamental purpose of engineering education is to build a knowledge base and attributes to enable the graduate to continue learning and to proceed to formative development that will develop the competencies required for independent practice (International Engineering Alliance, 2019).

Quality of engineering education is measured by professional bodies using two methods; outcomes evidence based criteria for evaluating education programmes and competency based standards for professional registration (International Engineering Alliance, 2019).

Two of the major quality assurance processes of engineering education programmes involves internal programmatic review and external accreditation. Both processes differ in their focus and intent and the preparation required by the programme teams and management. The two processes emphasise different aspects of engineering education (Quality and Qualifications Ireland, 2017).

Faculty staff view the programmatic review process as principally a review of the faculty / department and the accreditation process as a more rigorous review of the programme content. In recent years the accreditation process measures either the competencies achieved by students or the evidence of the achievement of learning outcomes by students (Engineers Ireland, 2010) (Society of Chartered Surveyors Ireland, 2012).

LITERATURE REVIEW

In engineering education quality assurance there are two main powerbrokers, the state and the professional bodies, acting as gatekeepers and controllers for the roll out of policy admission to the engineering profession.

The research literature has shown that internal and external evaluation of engineering education programmes, in regular cycles, is conducted worldwide. In some countries, accreditation is conducted by a government organisation. In others, the quality assurance process is

independent of government and is performed by private companies or professional bodies (Aqlan, et al., 2010)

In the United States of America, ABET evaluates engineering education programmes and uses the *ECriteria 2000* as the basis of their participation in international multi-national agreements and mutual recognition agreements (Washington Accord). In Europe, there are many policy developments including the Bologna Declaration. Guidelines for quality assurance have been developed by the European Association for Quality Assurance in Higher Education (ENQA, 2015). The establishment of the European Federation of National Engineering Associations (FEANI), the European Network for Accreditation of Engineering Education (ENAAEE) and the development of EUR-ACE® has created a common approach to accreditation and assists in simplifying different systems (FEANI, 2019) (ENAAEE, 2019).

In Asia, Australia and New Zealand have led the development of accreditation processes and were founder members of the Washington Accord. Some other countries are also members of the Accord (Japan, Malaysia, Taiwan, China etc.) (Patil & Codner, 2007). Thom (1998) argues that without engineering education professional body policies do not become reality and without the seal of accreditation, education does not become the route to election into a professional engineering association. The pursuit of accreditation has become mandatory for Higher Education Institutes as the consequences of not being accredited are dire for graduates who would not be able to practice as professional engineers (Said, et al., 2013). The purpose of accreditation is to evaluate engineering education programmes against standards agreed upon and accepted by the international academic community and relevant industry stakeholders (Aqlan, et al., 2010).

Irish Institutes of Technology hold Delegated Authority to make their own awards and are obliged to have regard to quality assurance guidelines issued by Quality and Qualifications Ireland (QQI) (Quality and Qualifications Ireland, 2016). All registered education providers are required to conduct cyclical programmatic reviews of their programmes. In addition, Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG) requires that Higher Education Institutions should monitor and periodically review their programmes to ensure that they achieve the objectives set for them and respond to the needs of students and society (European Association for Quality Assurance in Higher Education (ENQA), 2015).

The Programmatic Review process normally involves a root and branch examination of programmes of study and how they have been delivered in the previous five years and how they plan to be delivered in the subsequent five years. Programmatic Reviews are normally conducted on a department or faculty wide basis.

RESEARCH QUESTION(S)

The research question for this paper explores if the internal quality assurance programmatic review process can be enhanced by using the outcomes based methodology of the accreditation process, thereby bringing the two assessment types into closer alignment and creating only one quality assurance process.

This may allow for the establishment of a single collaborative quality assurance process for engineering education or facilitate sequential occurrence of the processes within the same timeframe.

METHODOLOGICAL APPROACH

As the research is designed as a qualitative study to gain insights from experts, the design philosophy supporting this research includes a pragmatic paradigm with a subjective ontology allowing multiple realities, an interpretative epistemology and axiology for value laden interpretation of qualitative research, using an adopted Delphi technique for data collection and the constructivist grounded theory to support the analysis of the data. The characteristics of these methodological approaches were examined to ensure that they were all compatible for this research methodology.

Significant consultation has taken place with the gatekeepers of these processes. The Technological Higher Education Association (THEA) was established in the early 2000's to represent the Institute of Technology sector. Under THEA, the Council of Heads of School of Engineering (COHSE) was established. Incorporation of the programmatic review process and

accreditation process into a single quality assurance process has long been an ambition of the COHSE.

The author prepared a discussion document and comparison analysis of the two processes in consultation with COHSE. The position paper concluded that there is considerable overlap between the programmatic review and accreditation processes and some realignment/amalgamation of the processes would achieve the same outcomes. Three COHSE representatives met with the THEA Council of Registrars and with the Registrar of Engineers Ireland who agreed in principle with the approach and recommended further consultation with QQI.

The researcher met with QQI and the Registrar of Engineers Ireland to consider if it is possible/practical to align the objectives of the programmatic review and Engineers Ireland accreditation processes. The researcher prepared 24 triangulation documents comparing the QQI Engineering Award Standards, the QQI Professional Award Type Descriptors and the Engineers Ireland Accreditation Criteria. There is over 90% alignment between these standards.

Action research intervenes in work practices to achieve change and improvement. The Delphi technique utilises action research to achieve consensus by using a series of rounds. Data collection and analysis proceeds in an iterative process until consensus/theoretical saturation is reached. The constructed knowledge will reflect both the researcher's and participant's views of the research area.

The main stages of the research are as follows:

Delphi technique round 1 – Semi-structured interviews

Delphi technique round 2 – Structured questionnaire using the findings in round 1

Delphi technique round 3 – Semi-structured interviews using the findings in round 2.

KEY FINDINGS

Twenty six semi-structured Interviews for the Delphi technique round 1 were held with a pre-determined multi-level expert group who had sufficient knowledge and experience of both quality assurance processes. The overarching themes that emerged from these interviews were categorised into those relating to the existing processes and those relating to new revised process(es).

The structured questionnaire for the Delphi technique round 2 was created directly from the seventeen overarching themes emerging from the round 1 interviews. The questionnaire was sent to all 26 participants from round 1 and 24 participants completed the questionnaire. The outputs from the questionnaires are currently being analysed.

For each sub-question a deeper analysis of respondent answers was undertaken by group type and engineering discipline to compare the responses by the various categories of respondents: Registrars, Heads of Faculty/School from both mechanical/electrical and civil engineering disciplines, Professional Body Registrars, Heads of Department from the engineering discipline areas, staff from the engineering discipline areas.

The round 3 semi-structured Interview questions will be generated directly from the outputs of the questionnaire from round 2 and will assist in finalising the outcomes of the research.

DISCUSSION

This research explores the possibility of aligning or combining the accreditation and programmatic review processes. Prior to the commencement of the data collection the researcher consulted with the main gatekeepers to the engineering profession and QQI to ensure that all agreed in principle with the ambition of the research. To establish the differences between the processes, a position paper, comparative analysis and triangulation documents were prepared which concluded that some realignment /amalgamation of the two processes would allow for the achievement of the objectives of both processes.

The round 1 findings have identified that the research participants are also very supportive of the possibility of aligning/combining the processes. Seventeen themes and categories that are likely to hinder the possibility of bringing the processes into closer alignment were identified.

Further exploration of these themes and categories through the round 2 questionnaire has captured the opinions of the participants and has facilitated comparison between the various groups of participants from senior management level to staff and between engineering discipline areas. Whereas all are supportive of the research ambition, the method of alignment/combination is still proving difficult to reconcile and other areas have been identified where clear protocols need to be established.

The major challenge for this study lies in keeping the gatekeepers informed of progress and keeping up to date with changes to the relevant policy documents over time as policies change in regular cycles. The findings of this study will bring to the fore the concerns and identify the obstacles that may prevent achievement of process incorporation/alignment. The benefit to the engineering community would be a reduction of process overlaps, significant saving in time and effort while ensuring both processes occur in the same time period.

CONCLUSIONS & RECOMMENDATIONS

In Ireland there are two major cumbersome quality assurance processes for engineering education programmes in place currently which differ in focus and intent but have considerable overlaps.

This research explores how the accreditation process could be incorporated into the programmatic review process to achieve closer alignment where the objectives of both processes can be met. The main themes and categories have been identified and are being considered in an iterative cycle to achieve consensus.

ACKNOWLEDGEMENT

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CDIO Open Day Learning Activity to Inspire the Next Generation of Engineering Applicants

Sheikholeslami, Ghazal Nortcliffe, Anne

Canterbury Christ Church University

anne.nortcliffe@canterbury.ac.uk

KEY WORDS: CDIO, Engineering Recruitment, Engineering Education

SUMMARY

The new engineering provision at Canterbury Christ Church University has adopted the Conceive, Design, Implement and Operate (CDIO) pedagogy approach. In particular the MEng, BEng and BEng with Foundation Year are grounded in the fundamentals of Physics and Engineering Science. To inspire the potential students on the open day we have developed taster sessions to develop their understanding of the important factors in these subjects. The taster sessions comprise a selection of activities in the form of practical sessions related to Engineering Programmes at Canterbury Christ Church University. The activities offer potential applicants a flavour of learning activities and aim to achieve the following learning outcomes:

- Working in small groups students:
 - Complete a preliminary engineering design exercise
 - Communicate their ideas.
 - Demonstrate an understanding of the project

This practice paper reviews this approach to engineering recruitment practice.

INTRODUCTION

The new engineering provision at Canterbury Christ Church University (CCCU) has adopted the Conceive, Design, Implement and Operate (CDIO) learning and teaching approach. The rationale for adopting CDIO is that it has been shown to close the engineering skills gap, and produces professional practicing engineers fit for purpose, (Crawley, et al, 2014). To support the student recruitment cycle, the University and the School of Engineering, Technology and Design run a number of open days and applicant days throughout the academic year. These open and applicants days support and inspire student applicants to apply and accept an offer on their programme of choice of study in engineering at CCCU.

A number of CDIO activities have been designed to showcase the learning approaches adopted on engineering programmes at CCCU and also to provide flavour to the different engineering programmes offered at CCCU. These CDIO open day activities at CCCU have been inspired initially by the Mechanical Design module (MECH113 & MECH114) in the active learning lab (ALL), at a different university where one of the paper authors was previously employed.

LITERATURE REVIEW

CDIO provides students with the opportunity to actively learn through ‘doing engineering’; Massey (2012) argues that this is more exciting and motivating than sitting in a lecture. The activity for CCCU applicant day/open day has been designed and based upon the vision of the “CDIO-based education”, (Sadchenko, 2016; Malmqvist et al, 2017; Yong et al, 2018) to enhance the fundamentals and integrate learning of professional skills such as teamwork and communication.

OPEN DAY ACTIVITY CHALLENGE

The aim of the CDIO open day activity is to inspire university applicants to apply and accept a place on an engineering programming at CCCU. The activity discussed in this paper is based

around an activity utilising LEGO® MINDSTORMS® robots (LEGO, 2019). This project-based learning for engineering approach, introduces students to the engineering mindset including critical-thinking, problem-solving as well as collaborative working skills.

DESCRIPTION OF INTERVENTION / PRACTICE

The CDIO activity used EV3 core set, iPads and stop watches.

The rationale for using Lego EV3 Brick is best explained by LEGO;

“The system includes the Intelligent EV3 Brick, a compact and powerful programmable computer that makes it possible to control motors and collect sensor feedback using the intuitive icon-based programming “(LEGO, 2019).

“The software is an easy-to-learn, easy-to-use software and the programming app are optimised for group use. Programming is done by dragging and dropping icons into a line to form commands allowing students to build simple programs, and then easily and intuitively build on their skills until they are developing complex algorithms” (LEGO, 2019).

Students are encouraged to work in pairs, or groups of three. Each pair/group is provided with introduction worksheet and related components, to start the session. The robots were already built in different shapes due to time limitation. The groups were responsible for planning a 30 minutes experimental work with the aim of optimising the robot’s program to follow the pre-designed path with different obstacles whilst reaching the finish line and then race among themselves.

The winning group are those who reach the finish line in the shortest time whilst successfully overcome the obstacles with a calibrated robot. This team was given a prize unique to School of Engineering, Technology and Design.

This CDIO exercise was designed in context to the engineering science and processes of calibration, programming and design of the speed in correlation with the pre-designed path, obstacles and several rotations. The exercise provides learning experience of;

- Software engineering through programming the system;
- Mechanical engineering;
- Electro-mechanical engineering;
- Mechanical operations of the lego robot servos and wheels, etc.;
- Control and instrumentation engineering;
- Calibration of the instrumentation and servo systems
- Systems engineering

EVALUATION OF INTERVENTION / PRACTICE

Each open day it was observed that the groups managed to show good understanding of the robots' designs, programming, calibration and aerodynamics by answering the popped question at the end of this activity.

One key aspect of the activity was that it indicated the applicants were able to demonstrate the Engineering Habits of Mind (EHoM) thinking skills, as defined by Royal Academy of Engineer, 2014). The experience was so inspiring and engaging that the greatest challenge was getting our students to leave the room!

During the first open day the following was observed:

- The students successfully completed the preliminary design exercise by working in a small group.
- All of the groups successfully reached the final line and managed to follow the set route.
- The students were able to communicate their ideas.
- The students came up with different strategies to finish the race
- The students were able to demonstrate an understanding of the project by answering the questions asked by lecturers at the end of the session.

We later repeated the same exercise at the outreach event of “Skinner Academy Day” at CCCU with the students of year 12. Learning from the previous exercise, we dedicated a longer time slot of 45 minutes to the experimental work. This provided students with additional time to explore more diverse ideas. Because the first exercise was such a success, on the second running we provided a more basic programme to students thereby raising the level of the challenge. Once more the students successfully completed the exercise. Students informed us that they found the exercise very engaging and interesting.

CONCLUSIONS & RECOMMENDATIONS

The CDIO open day active learning session can be developed and operated in a short amount time for the purposes of an open day. It provides prospective students with an insight into the learning and teaching used in the study of engineering and also introduces to the key principles and concepts underpinning the subject.

In future iterations we intend to develop and administer a questionnaire to assess student learning and to allow areas for improvement to be identified. .

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“No One Really Minded A Female Barmaid, But I Don’t Know They’d ‘Not Mind’ A Female Engineer” - One Student’s Journey.

Williams, Bill^{a,b} Chance, Shannon^{a,c} Direito, Inês^c

TUDublin^a CEG-IST, Universidade de Lisboa^b, UCL^c

bwbillwilliamsbw@gmail.com

KEY WORDS: Gender, Hero’s Journey, Monomyth

ABSTRACT

Attracting women to study engineering and retaining them has been a matter of concern for engineering stakeholders in recent decades. It has been suggested that the representation of women in engineering requires promoting more heterogeneous version of the profession. This longitudinal case study uses a structural narrative approach based upon Campbell’s monomyth of the hero’s journey to present the case of a female mature student facing economic and family challenges as she sets out on the path to become an engineer. The authors believe that access to the story of this young woman’s non-traditional path to becoming an engineer could encourage a more diverse range of young people to consider choosing the profession. It could also be useful for faculty to gain a deeper knowledge of the context and challenges of mature students and so be better able to provide or recommend support.

INTRODUCTION:

Faulkner (2007) quotes a senior engineer explaining their experience of engineering “It’s all engineering really – all nuts and bolts” and adding after a pause “Well nuts and bolts and people”. Faulkner goes on to observe that that most engineering programs give priority to the nuts and

bolts or technician aspects of engineering and little to the sociotechnical dimension. She suggests the attraction of engineering for some men is related to this concept of a technician “real engineering” and conversely this makes it less attractive to many women. She goes on to suggest that the representation of women in engineering requires promoting more heterogeneous versions of the profession.

To explore how such promotion could be accomplished in practice and to better understand female students’ experiences of engineering programs the authors began a line of research in 2013. They started by interviewing a broad and diverse set of female engineering students. The lead investigator travelled to multiple locations across Europe to gather data from students in three geographically and culturally diverse corners of the continent. During the Academic Year 2012-13, she conducted a first set of semi-structured interviews with 46 of the participants. Interviews varied from 45 to 120 minutes in length and were conducted on-campus at Dublin Institute of Technology (now part of the Technological University TUDublin), Instituto Politécnico de Setúbal in Portugal and Warsaw University of Technology in Poland. Since then follow-up interviews have been carried out with particular sub-sets of the original sample to provide a richer longitudinal characterization of the student experience.

RATIONALE

The authors characterize experience of a mature female student on the four-year engineering program using a narrative methodology based upon the hero’s journey monomyth framework originally proposed by Campbell to identify the common elements of the narrative myths handed down from ancient times. The framework has been employed in recent years to analyse both engineering student and faculty experience (Boklage et al., 2018; Cruz and Kellam, 2017, 2018).

AIM AND OBJECTIVES / RESEARCH QUESTION(S)

The research question addressed falls into the category described by Shavelson and Towne (2002) as a description of what happens:

Can Campbell's theory of the monomyth or hero's journey be effective in characterizing an exemplar student story by structuring it as a series of chronological events?

METHODOLOGICAL APPROACH

Due to the exploratory nature of the research, the authors chose a single-case study (Eisenhardt, 1989) to present the experience of one of the Irish students, Jean whose path falls somewhat outside that typically followed by engineering students.

KEY FINDINGS

Jean had originally gone to university on completing secondary school but dropped out after two years of little academic success. At the age of 26, after eight years of working as a barmaid and by now a single mother bringing up a three-year-old son, she decided to enrol on an engineering course at a Dublin university. The following table sets out her path as organised through the application of the monomyth of the hero's journey.

Figure 1: Jean's path as organised through the application of the monomyth of the hero's journey.

Monomythic code	Student journey	Quotation
The call to adventure	Jean went to university to study first law and then pharmaceutical science with financial support from her parents after completing secondary school. She was the first generation of her family to enter higher education.	"I didn't really care. I was there because I had to be, you know? And I was picking bad choices in courses because I'd think about, you know the money or something like that and I never really pursued Maths even though it was my strongest subject [in] all my schooling in primary and secondary."
Refusal of the call	After 2 years she dropped out, to the disappointment of her parents, and opted for work as a barmaid. Three years later her son was born and she was bringing him up as a single mother	"Like, I tried -- my first college course was law, ... and I, like, I hate reading. Like I'm not, I'm not great at English. I'm not great at writing -- I hated it and I left it. Next, [the] next year, I did pharmaceuticals. And I actually did like that -- but I was so bad at applying myself. So lazy. Smoked a lot of weed [ha, ha], so couldn't get out of bed. Missed a lot of practicals."
The first threshold	Jean aged 26, encouraged by some bar patrons decided to try to get on an engineering program. She passed the entrance exam with good grades in maths and after some uncertainty was eventually considered for state support as a higher education student	"And if I don't get that grant, I'm gone. Like I can't, my dad can't afford to pay my college. He's paid for it in the past, you know, like "Once bitten, twice shy," you know!"
Supernatural Aid and receiving an amulet	Pat, an older regular in the bar where she worked, who had a maths degree, encouraged her to apply for the entrance exam for engineering. He helped prepare for the entrance exam and gave her regular support while on the course.	"And, I forget, having a glass of wine [at the bar where she worked], or whatever, and Pat was there and I had to write the report. I'm a Liverpool fan as well, so I sat there watching. Liverpool were playing Madrid. I sat there writing the report, a glass of wine, and he called me over and I was talking to him, and I was telling him I spent so late in the library because I have no computer at home. And he just went and bought me a

		<p>laptop. Like, this is how much he believes in me!"</p> <p>"He'd ask me, "how you getting on in Physics? What ya doing?" Just say, I was like 'dimension analysis' And he was like -- because he loves all this -- and he'd be like, not quizzing me, but like, asking me dimension analysis of something. And you could see it in his face, he was like, "Good girl!" You know what I mean?"</p>
Belly of the whale	<p>She was older than other students, mainly young men, had never tinkered or done technical drawing; had family and work (barmaid) responsibilities; felt swamped but really enjoyed being on the program.</p>	<p>"This really is, kind of my last chance [laughs], you know? To get it right. So... so... just a little anxious about that. But I have got the mentality, it's just I take one day at a time now."</p> <p>"There's stabs of guilt as well, though, from like... you know from like my son. I got him into -- he's three -- so, I have him in a crèche as well. There's a lot of hours away from him"</p> <p>"Yeah, no I am loving it. I have to say!]"</p>
Road of trials	<p>After opting for electrical engineering, she later concluded it wasn't for her.</p>	<p>"When I first got into it, in my mind, I wanted to be an Electrical Engineer and then I did a couple of Electrotech classes, and I knew it's not for me. Look, I just -- I don't like it. I -- felt a bit overwhelmed"</p> <p>"Okay, Electrical Engineering is ticked off. It's not happening."</p>
Apotheosis	<p>She followed the Civil and Structural program and got high assessment grades</p> <p>Jean discovered that the people skills she had developed in her professional work were valuable in keeping student design teams productive.</p> <p>In her fourth year she successfully completed an internship in an engineering firm despite encountering some gender related issues.</p>	<p>"I'm a bar maid as well, you know, so, I've always been in a male-orientated kind of environment."</p> <p>"It's not manipulation, but I know how to talk to an 18-year-old boy"</p> <p>"But say walking through a construction site, with truckloads of builders, do know? And it's not necessarily a sexual thing. It's more, looking at you like 'why are you here? Do you know, and they probably think that you're Health and Safety or something like that and you're here to give them a hard time."</p> <p>"No one really minded a female barmaid, but I don't know necessarily</p>

		that they'd 'not mind' a female engineer. You know, I think that that has a bit more to work on"
Atonement with parent	Her parents recognised that she was doing well in her studies and supported her as much as possible	"My dad's okay, as well. Like my dad, my dad's quite--though he didn't go to college--he's quite smart. So um, but he's, you know a cab-man. So he's not very, I don't know, they don't like showing emotions. [laughing] You know! I'd probably get a little, like, squeeze to the shoulder when I graduate. And that'd be huge! [laughs] I won't know how to react to that."
Ultimate boon	She won an award at the university for the best final year thesis	"But like that's what I mean by I deserve it. Like I am able to compete, you know. My grades are good. So it's more realization that I'm doing good."
Master of both worlds and Freedom to live	Applied for graduate programs of a multinational firm	"Taking my first ever professional interview. With my first ever professional panel, you know? But I did well. Like, I actually am able to talk for myself." "I'm still I'm still quite driven by the same fundamental goals: to be financially independent. You know what I mean, to take care of my son"

DISCUSSION

We found that Joseph Campbell's (2004) theory of the monomyth or hero's journey resonated with our goal to smooth students' stories by structuring them as a series of distinct chronological events.

CONCLUSIONS & RECOMMENDATIONS

The authors believe that access to the story of this young woman's non-traditional path to becoming an engineer could encourage a more diverse range of young people to consider choosing the profession. It can also be useful for faculty to gain a deeper knowledge of the context and challenges of mature students and so be better able to provide or recommend support.

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Practical Teaching in Engineering Education: A Global Evaluation

Mistry, Tanisha

Knowles, Dionne

TecQuipment Limited. Nuneaton.

Dionne.Knowles@tecquipment.com

KEY WORDS: Practical Teaching: Engineering Education: Employability

ABSTRACT

Practical teaching in engineering education is recognised to be hugely important particularly for the employability of students. During an evaluation involving 114 academics from around the world, we investigated the degree of perceived importance relating to practical teaching elements within engineering courses at middle and higher education levels. In particular it reviewed how practical teaching is weighted in course grading, the time spent on practical teaching for learning, barriers to practical teaching, its role in employability, and preferences towards practical teaching equipment. In terms of students, it looks at their motivation for taking part in the sessions and their potential to increase employability. The results found that the large majority of academics believe that practical teaching is extremely important for employability and that 50% of respondents felt that 40-80% of time should be spent on practical teaching. Yet barriers make this difficult. Cost remains the biggest barrier, followed by availability of equipment and lab time available.

BACKGROUND

The appreciation that practical teaching is more effective for learning than passive theoretical based teaching, particularly in engineering subjects has been recognised for over 50 years, but in many cases lecture based teaching still dominates the curriculum.

Before investigating the importance of practical learning for engineering students the evaluation team briefly scanned the academic literature.

- *Motivation*

The effect of practical research on the motivation of students was a present theme in the study conducted by Savage et al (2011), which aimed to investigate motivational factors affecting engineering students at the University of Portsmouth. Out of the 24 students, one believed that practical work was the most effective way to learn. It was recommended that lecturers should give practical examples happening in the real-world when teaching the theory. Another student suggested that they would be more motivated to learn about a topic if they could see that it would be a benefit to them in 'real life', so by providing background information, lecturers can retain student engagement.

- *Employability*

A guide created by York and Knight (2016) focuses on embedding employability into the curriculum offers a valuable insight into the benefits of practical learning for employability. Interviews undertaken by 97 newly recruited graduates and 117 of their more experienced workplace colleagues indicated that practical problem-working skills were constituents of success in employment. It was mentioned that the problems faced by those studied were often 'multidimensional' and their solutions were 'ill-defined'. Those who were successful at managing these problems were said to have 'practical intelligence', described by Steinburg et al (2000) as a construct that is distinct from general intelligence. From this research, it is clear that the learning of practical skills and development of practical intelligence from carrying out practical tasks is beneficial to both employers and employees.

- *Potential Barriers to practical learning*

One area of practical learning that was not found whilst reviewing the literature, identifying a gap for this evaluation was the potential barriers that could restrict higher education institutions

when adopting practical learning. Specifically, relating to factors such as the cost, availability of equipment and teaching time available.

- *Bench-Top vs. Large Scale*

Within the engineering education teaching equipment market, it is often debated whether large scale or bench-top models of apparatus are more effective for teaching. It was identified that there would be value in establishing a true picture of the balance of perspectives. Specifically, what proportion of academics/technicians believe that it is important to learn on large-scale equipment that will exactly replicate what's in industry versus bench-top models that are more affordable and take up less space.

EVALUATION AIM

This evaluation aimed to investigate the degree of perceived importance relating to practical teaching elements within engineering courses at middle and higher education levels. In particular, it reviews how practical teaching is weighted in course grading, barriers to practical teaching, its role in employability and preferences towards practical teaching equipment. In terms of students, it looks at their motivation for taking part in the sessions and their potential to increase employability.

EVALUATION APPROACH

- **Sampling**

Using convenience sampling techniques, 114 academics and technicians in the engineering profession were surveyed from across the globe by two means: A telephone survey and digitally using SurveyMonkey. Figure 1 shows the global distribution of the sampling.

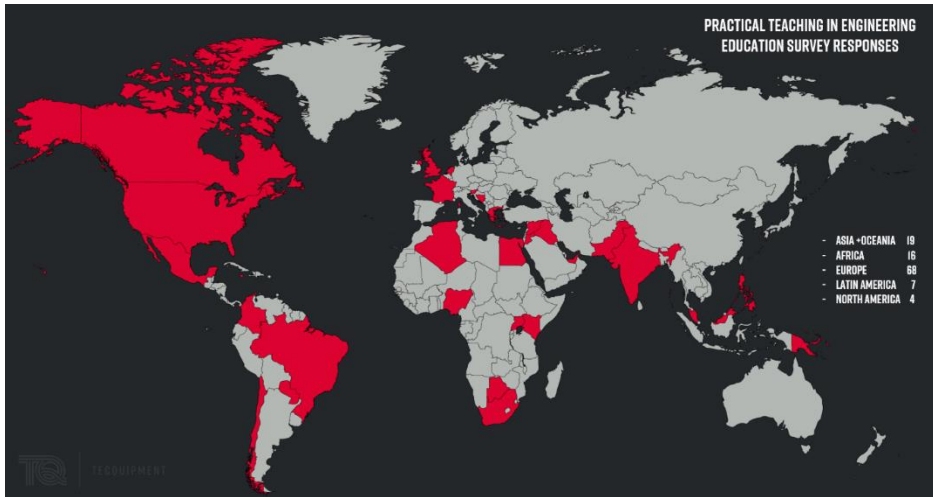


Fig 1: Survey Response by Geographical Spread

- Interview / Survey Questions Explored in the Evaluation

Seven key areas were explored during the evaluation. These are shown below in the format of verbatim questions:

1. What percentage of course grading is based on practical elements?
2. How much of your teaching time do you believe should be focused on practical learning?
3. How motivated are students to do practical sessions?
4. What do you believe would improve student's motivations to do practical sessions?
5. How important do you believe practical learning is for the employability of engineering students?
6. What are your greatest barriers to implementing more practical teaching aspects of engineering?
7. Does modular bench top equipment offer a better solution over larger scale industrial equipment?

KEY FINDINGS

An overview of the interview / survey answers is given and in some cases contextualized by previous studies.

- *Course Grading of Practical Learning*

This question was asked to establish what proportion of course grading is based on practical experiments versus theoretical methods through reports and exams. Historically, engineering courses have prioritised theoretical learning and examination to define levels of knowledge gained, with a small proportion of practical-based teaching assessment.

To test the current state of course grading across a range of higher education institutions, we asked academics to quantify the percentage of practical elements that are currently graded, the results are show in figure 2 below.

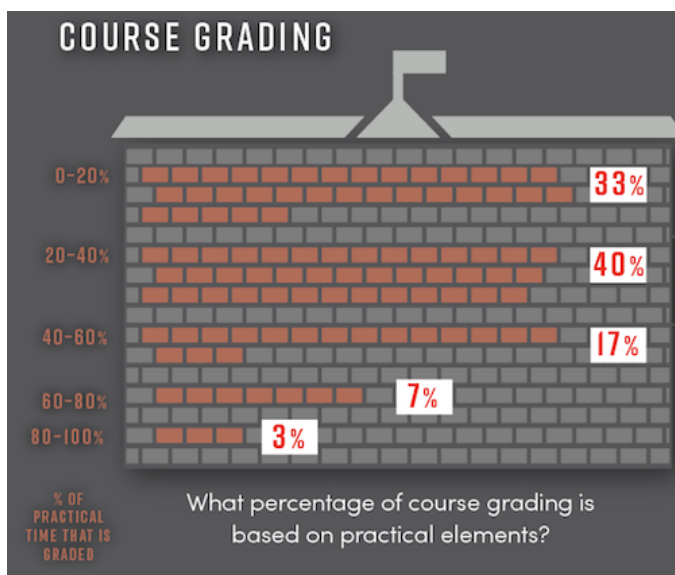


Fig 2: *Percentage of Graded Practical Learning*

As anticipated, the survey found the weighting of grading for engineering courses to still be significantly in favour of theoretical elements over practical.

- **How much time should ideally be spent teaching using Practical Learning approaches?**

The question asked how much time SHOULD be focused on practical hands-on learning. Over 50% of respondents felt that 40-80% of time should be spent on practical teaching. As anticipated, this was greater than the current level of practical grading.

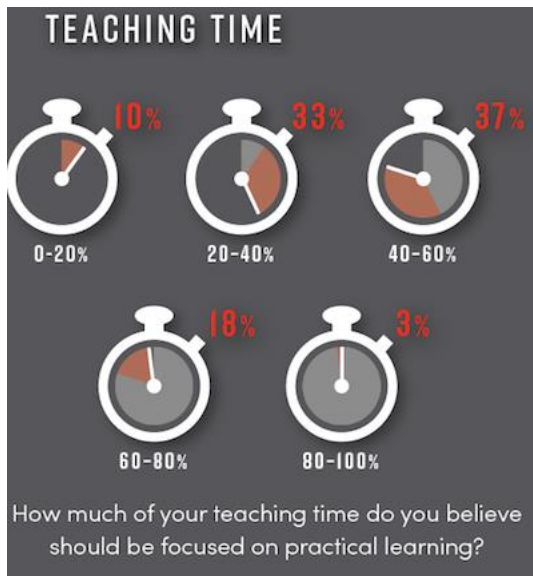


Fig: 3. Teaching time spent on practical learning

The reality is that implementing practical teaching into the teaching schedule has multiple barriers, which is looked at later in the report.

Further questions could ask what the actual versus aspired grading focused on practical teaching should be, and what the actual versus aspired teaching time focused on practical teaching should be. For practical teaching to serve its purpose, it needs to effectively develop scientific inquiry and exploration whilst simultaneously enhancing the teamwork skills required in the engineering industry.

- **Student Motivation**

To be the most effective, the engineering course must engage and have real-world applications. We asked academics how motivated they thought their students were to participate in practical sessions.

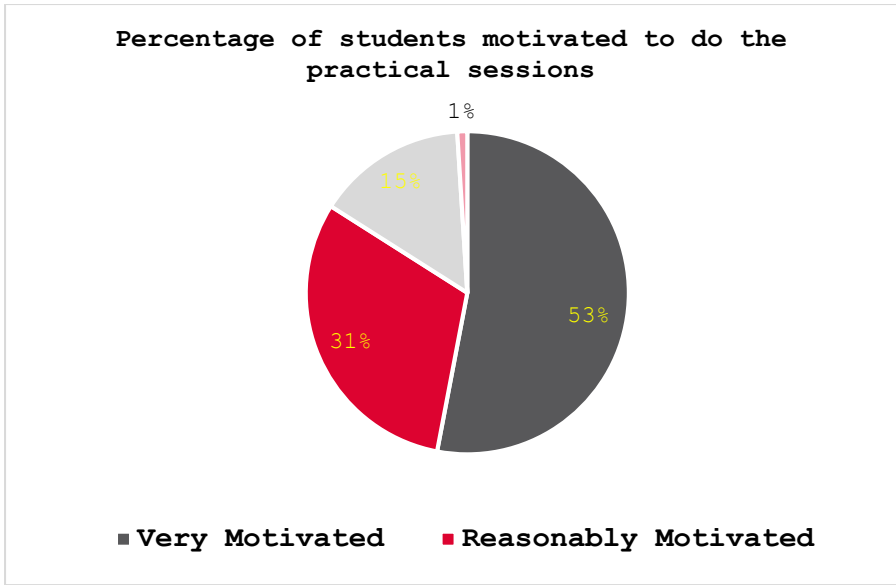


Fig. 4. How motivated are students to do practical sessions?

More than half of those surveyed believe their students are ‘very motivated’ to participate in practical sessions. According to Abeysekera and Dawson (2015), there is a link between motivation and learning capabilities with students learning more when hands on, as they are able to apply the theory to how things work within engineering industries. A significant proportion of respondents (46%) feel that students are ‘reasonably’ and ‘moderately’ motivated, illustrating there is work to be done to improve this situation across academia. We then asked the respondents how they thought motivation could be improved



Fig 5: Comments on how to improve student’s motivation

A sample of comments relating to improving student's motivation to take part in practical sessions. Responses to student's motivation were mostly attributed to the university and college's responsibilities. In particular relating to delivering more teaching that is practical, but also having an increased weighting on the practical elements that are part of the grading process. Other comments look at real life challenges that the industry faces and having smaller class sizes.

Savage and Birch (2008) found that engineering students demonstrate more intrinsic motivation than extrinsic and as a result they may more greatly benefit from having more freedom to determine their experiment protocols during practical sessions.

All the above points do not consider personal passion for the topic by the students. A few responses indicated that students needed a change in perception, by needing to understand the importance of practical teaching in their learning.

- Engineering Education Equipment Manufacturers

One responder believes that equipment manufacturers could help increase student's motivation for practical sessions. While some manufacturers offer user guides and workbooks, it maybe that more digital interactive experiences could be incorporated into the learning process to improve motivation and match student's digital experience expectations.

Another responder believed that student videos should be created by the manufacturers to help enhance the learning process. According to Travis Bergwall (Linkedin.com, 2019), 94% of teachers have effectively used videos during the academic year and have found it a very effective learning tool and seen as much better to teach students rather than giving them a textbook to learn (although the evidence for this statement is unclear).

- Employability & Life Experiences

With the end goal being to graduate with a degree in engineering and secure a job in the field, student's motivation can be heavily impacted by the current state of the job market. Engineering students not only need specific experience related to the engineering field, but also require skills that are seen to be transferable. According to Zaharim et al. (2009), engineering employers in Asia believe engineering graduates need these skills to be successful: Communication skills,

interpersonal skills, decision making and problem solving and knowledge of science and engineering principles.

Many higher education institutions partner with companies in industry, give students the opportunity to gain critical work experience.

Another big motivator for students would be to have real life engineering problems that students could find solutions for. One of the academics commented ‘*Students are motivated when we introduce real life engineering problems for them to solve.*’ This motivates students to really get involved in the problem, as it allows them to plan ahead, make critical choices and be thorough with their decision-making to come up with a solution. As this is related to current engineering issues, students could also compare their solutions with the real outcome of the results.

It may be useful for institutions such as universities and colleges to invest in new equipment to improve student’s motivation to engage in practical sessions. This would enhance their learning experience and in many scenarios ensure that they are learning on equipment that is matched to what is used in the workplace.

- *Employability*

The ultimate goal is to match what employers need. We asked our cohort “how important do you believe practical learning is for the employability of engineering students?”, the results are shown below.

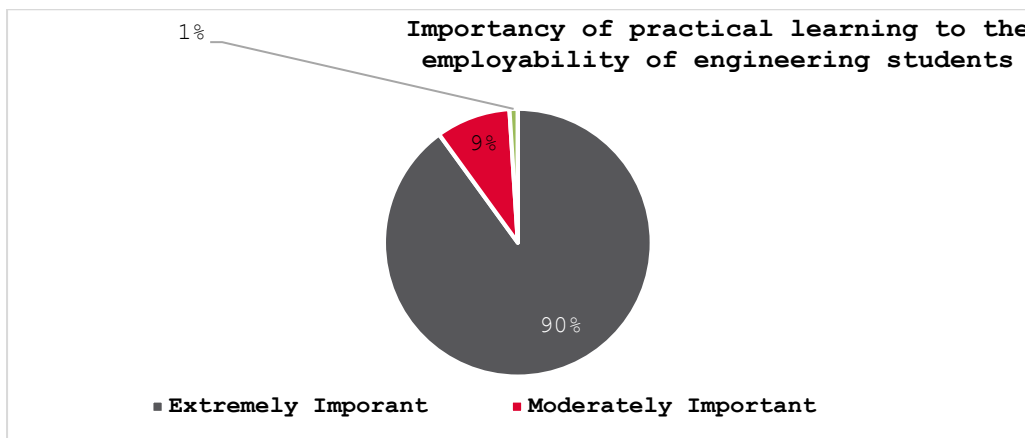


Fig: 6. How important do you believe practical learning is for the employability of engineering students?

Fig 7: Word Cloud showing the more prominent barriers to increase Practical Teaching Time

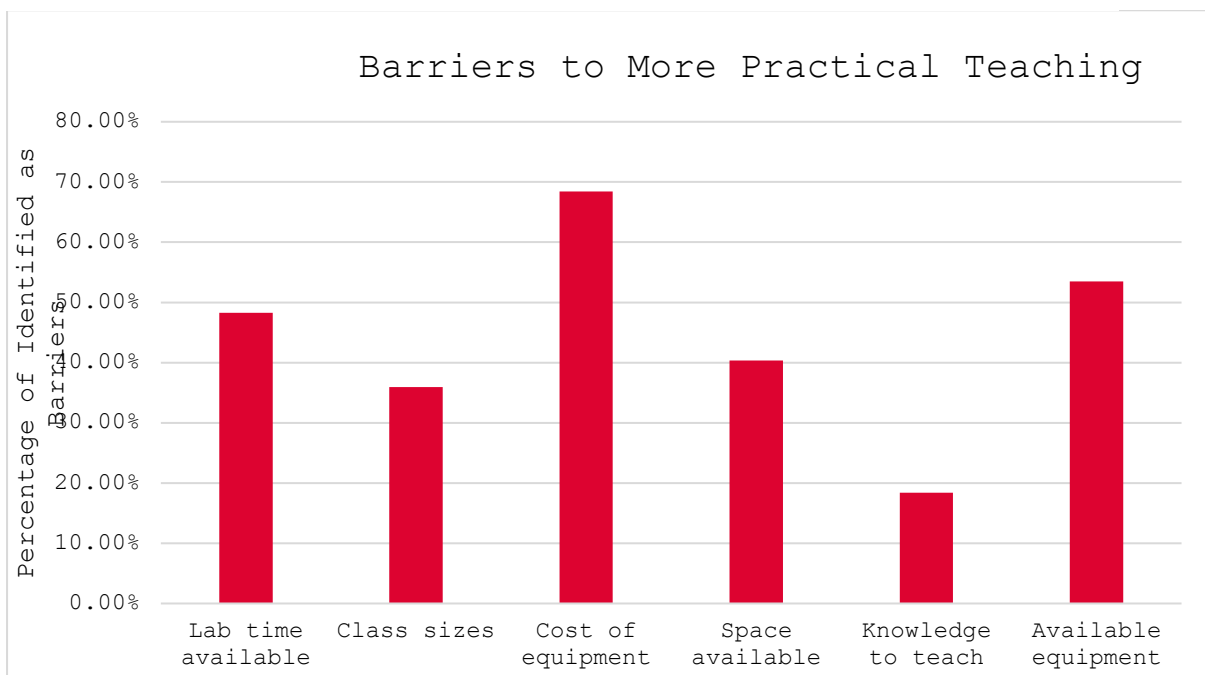


Fig: 8. Which of the following are your greatest barriers to more time teaching practical aspects of engineering?

- Cost of Equipment

Cost as a barrier can vary according to institutional purchasing approach and general budget pressures. Initial purchase price is often used as the metric for evaluating cost, but it could be argued that a more effective measure of cost in this case would be the lifetime cost to include quality and durability of the product.

- **Availability of Equipment**

Equipment availability is the second biggest barrier, which could suggest a number of things. Firstly, that equipment in the market doesn't meet their specifications. Secondly, that the right type of equipment is not available to meet changing social and technological advancements. Lastly, it could come down to the perceived local availability of getting equipment in their region.

- **Lab Time**

Forty-eight percent of respondents selected lab time as one of the greatest barriers to more practical teaching time. For these, the pressure is then on lab technicians/lecturers and in turn equipment manufacturers, to run these sessions as efficiently as possible and allow for quick and easy experiment change over.

- **Space Available**

In numerous institutions, the space available for practical teaching is a major issue. This was reported to be one of the greatest barriers by 40% of respondents.

- **Class Sizes**

The survey questioned whether current class sizes influenced the time spent on practical teaching. The results concluded that this was not seen as a big issue for implementing more practical teaching time. Further investigation could clarify what these class sizes are.

- **Knowledge**

In some engineering fields, there is a shortage of people with the skillsets required to teach specific areas of engineering, such as aerospace engineering. A not insignificant number of 18% felt this as a barrier to doing more practical teaching.

- Compact Vs Industrial Sized Equipment (Q7)

In the survey respondents were asked whether they preferred using modular bench-top equipment over larger-scale industrial equipment.

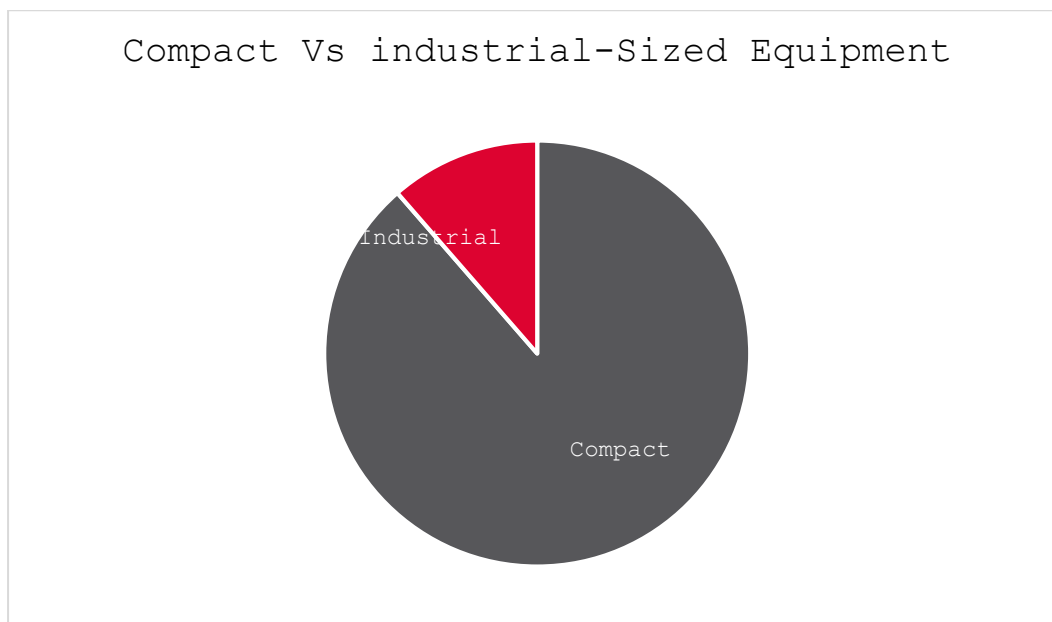


Fig: 9. Does modular bench-top equipment offer a better solution over larger scale industrial equipment?

Modular bench-top equipment that could be accommodated in relatively small lab spaces available were deemed dominantly as more suitable for practical teaching, compared to large-scale equipment. The balance lies in bench-top equipment being able to provide meaningful results, that reflect real life scenarios in the world of work.

When asked how academics could improve student motivation, one response preferred smaller equipment to use during lectures to provide a practical example and therefore motivate the students.

CONCLUDING REMARKS

This evaluation only recognises perceptions of academics in particular Lecturers and Lab Technicians within a predetermined set of organisations; future research could look at the perceptions of employers and students. The report supports other findings reviewed in the literature, while also adding more depth into methods of improving the situation. These

methods could be researched further to create a deeper understanding. In particular, under the questions about course grading and teaching time, in depth enquiry could make this clearer.

At a top level, the findings recognised that over 50% of respondents felt that 40-80% of time should be spent on practical teaching. It may well be that an increase in the practical graded elements might also further boost motivation. As predicted, cost and equipment availability were cited as the largest barriers to increasing the ratio of practical vs theoretical learning. One solution may well be to look at how universities and colleges can optimise the use of their laboratory facilities by providing shared spaces used across engineering disciplines.

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Theme 3: Technology Enhanced Learning in Engineering Education

Introduction

Contemporary engineering graduates are entering an increasingly globalised, complex and specialised workplace where the ability to switch between manual and digital tasks and communicate with a range of stakeholders across disparate physical locations are key skills. The use of technology in education helps to bridge the gap between theory and practice, physical and digital. It can bring the outside world into the classroom and take learning into the outside world. Apprentices can capture workplace learning using mobile technologies and then share them with their peers on a VLE. Tutors can build students' employability skills within the classroom; such as fostering problem-solving skills via game-based simulations; and the technology itself can give students access to otherwise inaccessible learning activities – such as conducting dangerous experiments using technology to control real equipment in a remote lab.

In addition to the pedagogic advantages of incorporating technology into the engineering curriculum, there are several practical advantages. Heavy marking loads can be reduced via computer assessment. Although the capabilities of computer assessment are quite limited at the present time, the technology is becoming increasingly sophisticated and has the advantage of reducing marker bias or even removing it altogether. Additionally, at a time when physical learning spaces are under increasing pressure, students can meet virtually with their tutor in online rooms or virtual labs.

The nature of online learning also means that student engagement is easier to monitor. Analytics can show us which activities were most popular with students, which videos were watched all the way through and which learning design generated the highest assessment scores – enabling tutors and institutions to continuously improve their curriculum and develop effective and engaged graduate engineers.

Edwina Jones, Education Innovation Group, WMG, University of Warwick.

Students' Perceptions of E-Learning

Muñoz-Escalona, Patricia^a, Marzano, Adelaide^b Vichare, Parag^b, Dunn Meg^b, Lazar Irina^c, Soares Filomena^d

Glasgow Caledonian University, UK^a, University of the West of Scotland, UK^b, University of Bristol, UK^c, University of Minho, Portugal^d.

patricia.munoz@gcu.ac.uk

KEY WORDS: E-Learning, Tools, Engineering, Students, Higher Education

ABSTRACT

Data regarding students' perception towards E-learning tools was collected through a survey and a focus group in different institutions (Scotland, England, Portugal) at different levels in Higher Education in the area of engineering. The purpose of this study was to have an understanding on students' perception towards E-learning tools as well for academics to reflect on how much effort has been made in including an innovative learning environment.

INTRODUCTION

Generation Z students, were born at the apex of technology and the internet; they have grown up around WiFi- laptops, video games, etc., so they are interactive, experts in technology and have high expectations of immediacy (Correia and Bozutti, 2017). Generation Z have also been defined as a unique and truly digital native generation of students born between the mid-1990s and 2012 (Seemiller, 2016); this means that they expect the incorporation of more technology in our teaching approaches, accompanied by more hands-on activities in classes (Malat, et al, 2015). However, since not all students belong to Generation Z, a more realistic approach is to refer to 'visitors' and 'residents' which is the term for digital users/online engagement (White and Le Courne, 2011). As academics, it is important to recognise the value of incorporating e-

learning activities in our teaching in order to motivate students and provide them with an opportunity to interact and engage with peers in cooperative and collaborative learning.

RATIONALE

Due to the evolution of technology e-learning tools are not been defined as a single term, and different researches refer to them as “an information system that can integrate a wide variety of instructional material” others as “technology intervention in the learning process” (Sun, et al, 2008 and Lee, et al, 2011). Students’ motivation and engagement in their learning process should be in constant review in order to enhance students learning experience. Motivation is an essential factor for students to learn and despite Generation Z students were born in the apex of a technological era and they expect the inclusion of technology as part of the teaching approaches (Correia and Bozutti, 2017), they also must have a positive attitude towards IT (Sun, et al, 2008). Previous research also highlighted that in order to provide a successful learning experience and make activities interesting to learners, proper and clear instructions must be provided (Keller and Suzuki 2010).

Technology Acceptance Model (TAM) allows to trace the impact of external factors on internal beliefs, attitudes and intentions. Figure 1 shows how the model works where behavioural intention to use (BI) is determined by the person’s attitude towards using system (A) together with its perceived usefulness (U), (Fred et al, 1989).

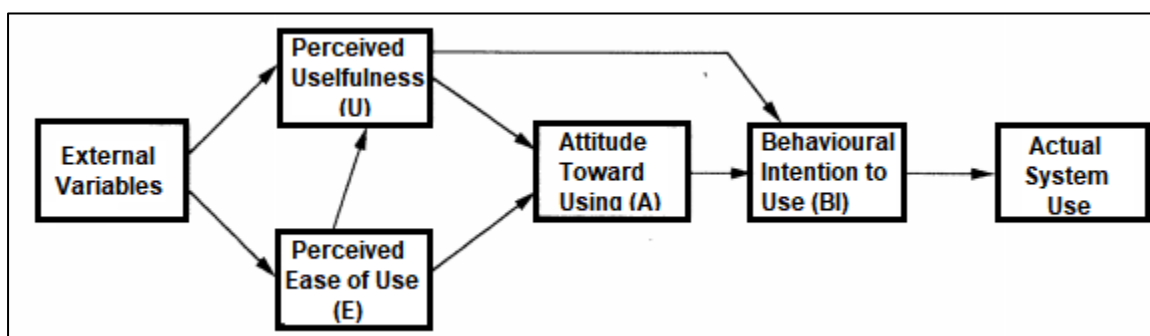


Figure 1. Technology Acceptance Model, TAM (Fred et al, 1989)

STUDY AIMS

This study aimed to:

- Establish baseline of students’ perception of e-learning tools
- Academics to reflect on implementation of e-learning tools in their teaching practice.

METHODOLOGICAL APPROACH

In order to collect information regarding students' perception towards E-learning tools a survey for engineering students at different levels of mechanical engineering degree at four different institutions was conducted. The survey was conducted to full time undergraduate students and to graduate apprentice students. Table 1 and Table 2 show the number of participants and their demographic details.

Table 1. Demographic details of participants in Full Time Education

Level	Study	# Students	University	Location	
1	1	Mechanical Engineering	50	A	Scotland
2	2	Mechanical Engineering	41	A	Scotland
3	3	Computer Aided Mechanical		B	Scotland
4	3	Mechanical Engineering	24	C	England
5	1	Integrated Master of Industrial Electronics Engineering and Computers	41	D	Portugal

Table 2. Demographic details of participants in Graduate Apprenticeship (GA) scheme

Level	Study	# Students	University	Location	
1	1	Mechanical Engineering	7	A	Scotland
2	1	Mechanical Engineering	5	B	Scotland
3	2	Mechanical Engineering	5	A	Scotland
4	2	Mechanical Engineering	5	B	Scotland

In order to further obtain and compare students' perception towards E-learning tools a focus group of 7 students in Level 2 from University A in mechanical engineering degree was also conducted. The session lasted an hour and questions followed the TAM model as described in the rationale. The focus group results were analysed following a qualitative approach. Limitations that should be considered are i) small number of respondent and ii) high degree of subjectivity.

Table 3. Demographic details of participants in the focus group.

	Age	Gender	Student
1	22	F	Erasmus
2	20	M	Home Student
3	19	M	Home Student
4	19	M	Home Student
5	21	F	Home Student
6	22	M	Home Student
7	21	M	Home Student

KEY FINDINGS

Results from the survey are observed in Table 4 for Undergraduate students and Table 5 for graduate Apprentice students.

Table 4. Results from students at different levels in Full Time Education.

	Level			
	1 (UK)	2 (UK)	3(UK)	5 (Europe)
Do you know what e-learning tools are?	Yes: 54% (27) No: 12% (6) Not sure 34% (17)	Yes: 63.7% (37) No: 36.2% (21) Not sure: 0% (0)	Yes: 37.5% (9) No: 12.5% (3) Not sure 50% (12)	Yes: 48.8% (20) No: - Not sure 51.2% (21)
Have you used e-learning tools in the past?	Yes: 54% (27) No: 38% (19) Not sure 8% (4)	Yes: 55.2% (32) No: 5.2% (3) Not sure: 39.6% (23)	Yes: 62.5% (15) No: 29% (7) Not sure: 0% (0)	Yes: 48.8% (20) No: 0% (0)
Rate your e-learning tool likeability	1: 4% (2) 2: 2% (1) 3: 32% (16) 4: 34% (17) 5: 8% (4)	1: 0% (0) 2: 0% (0) 3: 50% (29) 4: 50% (29) 5: 0% (0)	1: 0% (0) 2: 4.2% (1) 3: 37.5% (9) 4: 25% (4) 5: 8.3% (2)	1: 0% (0) 2: 7.3% (3) 3: 29.3% (12) 4: 36.6% (15) 5: 22% (9)
Most popular positive words defining e-learning tools	Free Accessible Fast	Practical Accessible Effective	Convenient Accessible Useful	Easy Accessible Fast
Most popular negative words defining e-learning tools	Need internet Confusing impersonal	Need internet Confusing impersonal	Need internet Self-discipline impersonal	Need Internet Crash Slow
Name any E-learning tool you have used in the past	Blackboard: 32% (16) Others: (Moodle, Glow): 20%	Blackboard: 56.8% (33) Others: Google classroom, conteudos: 12% (7)	Blackboard: 42% (10) Others: (Khan Academy, BBC bitesize, Polley, other websites: 33%	Blackboard: 56% (23) Moodle: 12% (5) Others: (Code academy, Khan academy: 14% (6)
On a scale of 5 (highest) to 1 (lowest) how important is it to use E-learning tools	1:0% (0) 2: 21% (1) 3: 25%(6) 4:17%(4) 5: 1%(2)	1:0% (0) 2: 5% (3) 3: 27.6%(16) 4: 53.4%(31) 5: 6.9%(4)	1:0% (0) 2: 21% (5) 3: 25%(6) 4:17%(4) 5: 1%(2)	1:0% (0) 2: 2.4% (1) 3: 10%(4) 4:31.7%(13) 5: 53.5%(22)

Table 5. Results from Graduate Apprentice (GA) students at different levels.

	Level			
	IA (UK)	IB (UK)	2A(UK)	3B(UK)
Do you know what e-learning tools are?	Yes: 56% (5) No: 11% (1) Not sure 33% (3)	Yes: 40% (2) No: 20% (1) Not sure: 40% (2)	Yes: 89% (8) No: 11% (1) Not sure 0% (0)	Yes: 100% (7) No: 0% (0) Not sure 0% (0)
Have you previously used e-learning tools	Yes: 78% (7) No: 22% (2) Not sure 0% (0)	Yes: 40% (2) No: 60% (3) Not sure: 0% (0)	Yes: 78% (7) No: 11% (1) Not sure: 11% (1)	Yes: 71% (5) No: 29% (2) Not sure: 0% (0)
Rate your e-learning tool likeability	1: 0% (0) 2: 0% (0) 3: 0% (0) 4: 56% (5) 5: 33% (3)	1: 0% (0) 2: 0% (0) 3: 60% (3) 4: 40% (2) 5: 0% (0)	1: 0% (0) 2: 0% (0) 3: 0% (0) 4: 67% (6) 5: 33% (3)	1: 0% (0) 2: 0% (0) 3: 43% (3) 4: 28.5% (2) 5: 28.5% (2)
3 most popular words to define e-learning tools	Easy Accessible Convenient	Practical Accessible Effective	Convenient Accessible Easy	Accessible Convenient Practical
3 most popular words to define worst things about E-learning tools	Need internet Crash Confusing	Need internet Confusing impersonal	Need internet Crash Confusing	Need internet No Support Crash
Name any E-learning tool you have used in the past	Blackboard: 44% (4) Maple TA: 33% (3)	Moodle: 40% (2) Others:(Khan Academy, BBC bitesize: 40% (2)	Blackboard: 56% (5) Maple TA: 44% (4)	Moodle 86% (6) Others: Khan Academy, BBC bitesize: 50% (3)
In scale 1 to 5, where 5 is the highest score, how important you think is to use E-learning tools	1: 0% (0) 2 11% (1) 3: 44.4% (4) 4: 33.3% (3) 5: 11% (1)	1: 0% (0) 2 0% (0) 3: 20% (1) 4: 40% (2) 5: 20% (1) Not answered: 20% (1)	1: 0% (0) 2 0% (0) 3: 11.1% (1) 4: 33.3% (3) 5: 33.3% (3) Not answered: 22.3% (2)	1: 0% (0) 2 0% (0) 3: 14.4% (1) 4: 28.5% (2) 5: 57.1% (4) Not answered: 0% (0)

DISCUSSION

From Tables 4 and 5, it can be observed that at least 37.5% of undergraduate students know what E-learning tools are, with a maximum of 81% of the students in undergraduate full time (Level 2) and 100% for GA at level 3, however this outcome does not seem to be very clear as when asking if they have used E-learning tools in the past 39.6% of students (Level 2), answered that they were not sure and 29% of GA students answered that they haven't used E-learning tools

When rating students' likeability towards e-learning tools, in general students' likeability was scored 3-4 out of 5 (being 5 highest score) for undergraduate and 4-5 for GA. This is probably related to the fact that GA programme involves more distance learning, making students more prompt of using E-learning resources. When asking students to provide 3 words to define e-learning tool, the most popular for all levels was accessible, fast and easy. When asking for 3 words to define worst thing about E-learning tools, the most popular were: internet dependency, impersonal and confusing. Having students including the word "confusing" as one of the most popular words to define worst thing about e-learning tools shows how important instructions are and how important this need to be clear for students to engage on the activity. This is in agreement with research conducted by Keller and Suzuki (2010).

From the Focus Group conducted to level 2 undergraduate students, 89% of the students felt that computers/laptops helped them to use E-learning tools and that they were great to use as these tools avoid arranging physical meetings as everything was done online, however it was highlighted the importance of reliable internet connection to undertake any task involving E-learning tools.

In regards to the usefulness of E-learning tools in engineering courses, 87% of the students agreed that if time is not an issue, assessment/activities involving E-learning tools will engage them, however 80% of the students prefer a blended approach as everything online can be an issue for some students (i.e. migraines). A positive thing is that by doing online activities, no paper is printed contributing to the environment.

Students highlighted that digital material is easy to download, the major problem is related to the submission process as 68% of students commented that they had doubts if the submission was conducted correctly due to lack of a notification of submission.

When discussing the attitude/enjoyment towards using e-learning tools, 35% of the students mentioned that using the word "enjoyment" was too strong as sometimes it can be ambiguous and is enjoyable only when the activity is 100% structured and no doubts are raised. Also 93% of students mentioned that a schedule for each activity was expected as this makes things easier and sometimes academics don't provide this.

When students were asked to describe E-learning to a non-student (Behavioural Intention to Use), the majority described it as “E-learning is learning using internet; is like information in paper but online”.

When discussing if they could choose between E-learning approaches and face-to-face 100% of the students attending the focus group preferred face-to-face as they could ask questions and things were easier to take when meeting face-to-face.

REFLECTION

Based on these results it is clear that when applying E-learning tools in students’ assessment it is important to highlight the tool been used and define it as an E-learning tool. It is also important to keep in mind that instructions should be clear and well structure if we want students to engage and enjoy the activity.

SUMMARY OF FINDINGS

- E-learning tools are enjoyable if they are well explained, however 80% of the students would prefer a face-to-face approach
- 68% of the students have doubts if submissions have been done correctly as sometimes no notifications are received (internet/technology not trusted 100%).
- Students seemed not to be 100% clear on what E-learning tools are.
- The 3 most popular words defining E-learning tools are: accessible, fast and easy
- The 3 most popular words defining worst thing about E-learning tools are: internet dependency, impersonal and confusing.
- The Graduate Apprenticeship programme allows more involvement with online activities (E-learning tool) increasing students’ likeability and recognizing its important towards them, especially at later years in their degree

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Using Computers for End of Year Examinations

Rossiter, John Anthony^a

Department ACSE, University of Sheffield, UK.

j.a.rossiter@sheffield.ac.uk

KEY WORDS: Examinations, Computer Assessment, Student Working, Reliable Assessment, Objective Assessment

SUMMARY

This proposal suggests some reasons for and consequences of changing assessment types away from traditional paper based exams. The main intention is to instigate some discussion with delegates. More specifically, consideration is given here to the potential of modern computer quiz environments to capture the same assessment information as a hand written paper and indeed to offer significant benefits to both staff and students.

INTRODUCTION

Assessment is a core part of any University degree and thus the design of these is important. However, assessment marking is a significant load for academic staff and indeed, at times, could constitute an unreasonable load. Marking by hand can take 15-20 min for a typical engineering script/assignment, so with a moderately large class of 200 students, this equates to around 50-70hrs, and that is assuming the staff member can concentrate clearly and work continuously. In practice, due to the requirement for fast turnaround times for feedback with assignments and/or reporting, as well as staff having multiple different cohorts/assignments to deal with simultaneously, such long marking times are typically impossible. Where class sizes rise to 300 and 400, this issue is magnified further, still.

In the context of assignments, there have been moves to adopt computer aided assessment (CAA) for many years (Croft et al. 2001, Rossiter et al. 2005, SIGMA, STACK), that is, a scenario where the student answers to an assessment are collected and marked by a computer, typically via a quiz engine. In particular in the mathematics community (Lawson 1995, Sim et al. 2004) these were popular with students as the CAA offered multiple benefits such as: (i) instantaneous feedback on submissions – no need for staff to mark; (ii) 24/7 access to submissions and the ability to self-test; (iii) incentives to keep on top of their studies. Such software is now also widely used in schools for home works (e.g MyMaths).

The author took these ideas and adopted them within engineering modules and, unsurprisingly, found similar positive outcomes (e.g. Rossiter et al. 2004, Rossiter et al. 2007) and with the additional confirmation of the fact that students will often only engage effectively if there is some reward by way of marks for doing so. There is an initial substantial overhead in creating the quizzes and question database, but thereafter this can be reused, maintained and updated with relatively low effort.

Using quiz engines for assessment is not however a win-win scenario and the most common complaint, albeit from only a few students, is that there are no marks for working; questions are marked right or wrong. This observation alone is probably the main reason that staff have not considered such assessment regimes for end of year examinations where one might expect a sizeable proportion of the marks to be available for 'working' and other learning outcomes less easily captured in a simple computer question (Schoen-Phelan and Keegan 2016, Lawson 2002). This discussion paper aims to challenge that assumption and argue that in fact end of year exams based on a quiz engine may provide a more objective and fair mark than a hand written examination (Greenhow 2015), as well as cover a wider range of learning outcomes than typically perceived.

Section 2 discusses some weaknesses of traditional hand written exams, section 3 considers how we might improve assessment thus leading into section 4 which proposes the use of CAA tools. Section 5 gives some evidence from actual usage and the discussion paper finishes with some concluding remarks and an invitation to discuss.

WEAKNESSES OF END OF YEAR PAPER EXAMINATIONS

It is not the purpose of this paper to review different assessment types and indeed the potential role of these is widely discussed elsewhere (e.g. Henri et al. 2017). This paper assumes that the assessment needs to be tailored to the learning outcomes and accreditation requirements (Passow and Passow, 2017) and focusses on some aspects of assessment of core skills, analysis and interpretation which are particularly prevalent in engineering, especially in early years.

It is accepted that CAA is very effective at assessing low level learning outcomes (Conole and Warburton, 2005), for example routine calculations, memorisation tasks, and simple yes/no questions. Consequently they are good for encouraging engagement and progress with the base level learning outcomes of a module. Conversely a typical end of year exam question has multiple parts, for example:

1. Base level introductory parts and computations that all students should manage.
2. Utilisation of solutions from the base level to more challenging problem solving and application. Good students should manage this.
3. More open-ended parts requiring application and interpretation not explicitly covered in lectures and allowing the very highest marks.

Marks for working could typically be awarded in parts 2 and 3, whereas for part 1 the mark scheme is more likely to be correct/incorrect. However, in some engineering topics, especially those with a more mathematical focus, there is likely to be a significant overlap between parts 1 and 2 with the consequence that a larger part of the mark scheme is constructed as correct/incorrect in that, evidence of correct working is evidenced by the computations alone. In other words, if the computation is incorrect, the student is likely to score zero for that part of the mark scheme, irrespective of what they have written. This may seem somewhat unfair, but could be true for simple practical reasons:

- Computations in part 1 should be straightforward and act as an entry requirement for the higher marks. (Good question design focussed on understanding not number crunching should rarely require students to use a calculator.)
- A staff member marking several hundred scripts needs to ensure consistency across all students and thus needs judgements which are as objective as possible. It is easier to do this with a precise mark scheme capturing core steps with small marks for each.

- Where students have made a computational or other error, there is often a significant amount of guesswork by the examiner with regards to what the student has actually understood and this means examiners are reluctant to award more than notional marks, especially given they need to treat all students who will have a variety of errors equivalently.
- A typical student script is messy, disorganised and often hard to read which means the examiner may have difficulty discerning student intent and sometimes, even identifying where the student is placing their proposed answers. This increases the reluctance to give significant marks for working.
- Questions often have a clear story and thus later parts rely upon correct computations in early parts; to remove this dependence makes questions less valid, authentic and interesting. If students make fundamental numerical or other errors early in the question, they cannot make meaningful progress with the latter parts and thus, any working thereafter is likely to be largely unmarked as examiners cannot reasonably check, and treat consistently, dependent student computations (for 200+ students) where early errors have been made.

In summary, for some engineering topics, the ability of students to achieve marks ‘*for working*’ is much less than both they, or indeed the examiner, may believe. Practical mark schemes often breakdown a question to 1% and even 0.5% components for which students either receive a mark or don’t.). Hence, paper based examinations are neither as fair nor objective as some might believe and indeed there can be an enormous amount of subjectivity and inconsistency in how many marks are awarded for incorrect solutions.

The breakdown into multiple small marks also increases transcription errors from correctly adding up all the component marks, especially given students often spread their answers over multiple pages and answer booklets; in the author’s experience adding up errors occur in about 5% of papers for large cohort examinations (before 2nd marking/checking).

Remark: *For exams with discussion/essay/design type questions the above reflection does not apply; the author includes these aspects elsewhere in the overall assessment regime if required.*

IMPROVING ASSESSMENT FOR STAFF AND STUDENTS

This section looks at possible solutions to the weaknesses described in the previous section, that is, how do we manage staff marking loads for large classes and, how do we ensure our assessment schemes are objective rather than subjective and of course reliable? University assessment must demonstrate rigorous quality assurance procedures and have some attributes as indicated below (list not comprehensive).

- Exam questions must be unambiguous. Wording and presentation should be checked carefully.
- Marking schemes must be defined to ensure consistency of treatment of students.
- Collation of marks into University databases should be reliable (error free).
- Expectations are consistent with equivalent modules elsewhere.
- After marking, all scripts are checked by an independent person.
- The assessment allows students to demonstrate ability across a full range of performance levels and also covers the required learning outcomes.
- Students should be able to complete the assessment in well under the time allowed.

In the context of this paper, we focus on consistency of treatment of students and assessing across the whole range of abilities, the other attributes being implicit. Furthermore, this discussion paper takes as a context a topic where assessment of calculations form a significant part of the learning outcomes. The argument is that computers are far better than humans at most aspects of marking some things:

- Computers assess numerical answers more reliably than humans and force students to be clear in what they submit.
- If students make decisions/interpretations from a given subset, a computer can easily award marks according to how the students have made their selection.
- Computers can deploy negative marking and weighted schemes easily and handle all the adding up and porting to excel or other database instantaneously.
- After the event, we can easily modify a mark scheme (as examiners often do) and the computer will instantaneously update the marks for the entire class.
- Computers do in seconds what could take academic staff weeks and also, computers will do, in principle, with no errors.

Hence, the main premise of this paper is as follows. Where we can justify that the learning outcomes can be fairly assessed with questions delivered and marked by a computer, this is likely to be much fairer and more efficient than a hand marked examination. A few illustrations will be given in a later section which indicate that the mark profiles from such examinations are consistent with what would be obtained from an equivalent paper based examination and thus have not been challenged by exam boards or external examiners.

CHALLENGES WITH END OF YEAR COMPUTER EXAMINATIONS

Examiners have two core challenges to face when designing an assessment:

1. The authenticity of the assessment type for holistic assessment of student learning and ability to apply their learning, in the context of the module learning outcomes.
2. Managing student expectations of the process, that is, do the students perceive the assessment to be fair and allowing them to demonstrate their learning.

It is obvious that, especially with large classes, there are significant efficiency gains to be had by adopting computer marking; marking a computer exam is instantaneous and the marks are automatically and reliably tabulated into a useful computer format such as excel. To ensure a computer marked assessment fairly distinguishes between different student competence, it is important to identify clearly the different learning outcomes. What evidence is needed to award a pass? What evidence is need to award a good or excellent performance? How can we mitigate against a silly student typo early in a question so they can still achieve a good mark? How can we capture correct student working, even when some computations may be incorrect?

The CAA design should, as far as possible, ensure that calculation/observation dependencies are in parallel paths so that students can make correct progress on some later parts even if some of an early part is incorrect. One can also insert standalone questions for higher learning outcomes which are not dependent on previous computations, for example where a solution/graph is provided and the focus is on interpretation, analysis and design. For assessing student intention/working, use can be made of multi-choice questions whereby students must select from a number of possible statements.

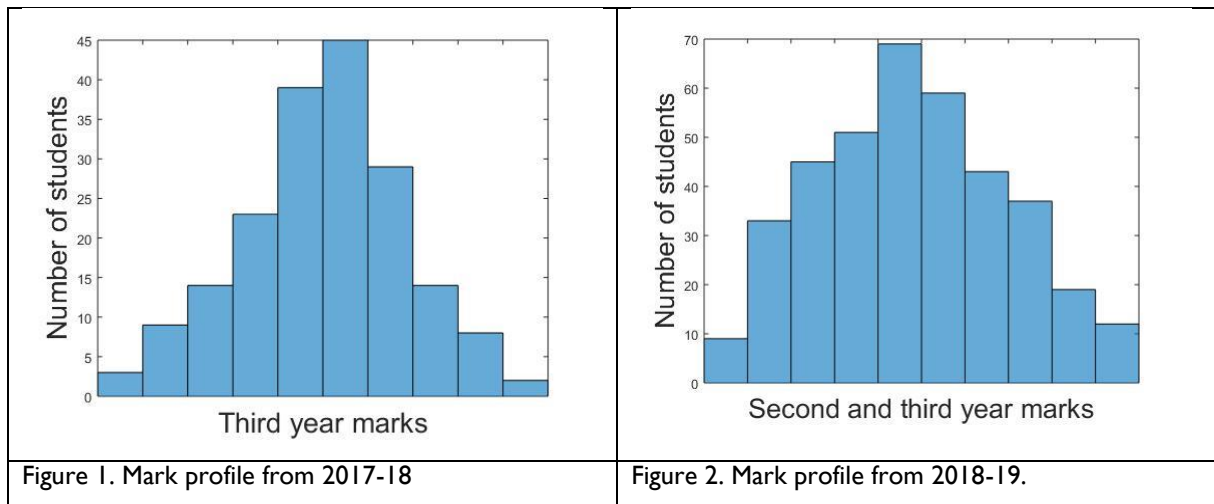
Consider a typical control question which involves the analysis and design of compensators for a system $G(s)$.

- The foundational knowledge will require sketching of the common plots (e.g. Bode) where the characteristics can be captured and assessed with simple question types.
- Following parts use interpretation of the sketches and use parallel threads so that students can get some marks even if their sketch is not totally correct.
- More challenging aspects and the highest marks involve detailed analysis and design, and may only be accessible to students who have the earlier parts totally correct.

From the author's perspective, assessment design is manageable and can be defended as being as robust as a paper based examination, if not more so. However, a second challenge is student perception. Staff need to work hard with students to explain to them and convince them that the examination is fair as this is different from what they are used to. In the author's experience often students just take it for granted that this is how the module is being assessed and are quite content but occasionally (for the author once out of five usages) a few students can create a fuss because it does not match their preconceptions of what assessment should look like; this then needs careful management.

EVIDENCE FROM 2017-2019

The author has used CAA for end of year examinations on three different modules in the last two years. Each time the mark profile (e.g. figs 1-2 for a process control module) was very similar to that achieved when the same module had a paper based examination. The main exception was that students scoring a clear fail may fail even worse as they will not get the over generous 1-2% here and there for writing something vaguely relevant.



CONCLUSION

The potential downside of computer exams is the desire to see ‘*student working*’ to give a fair assessment, as inevitably the typical end of year examination mark scheme recognises both correct computations and also a correct approach or thinking. A counter argument is that one must not fall into the trap of ‘*its always been this way*’ and assume that past practice is necessarily best practice; for example it is already well publicised that traditional lecturing has a limited value. Instead, one needs to consider whether evidence of student working and thinking can be collected and assessed another way. The author’s viewpoint is that the examination scripts written by many students are so scruffy and disjointed that it is often impossible to give a fair objective assessment and marking of what they have and have not understood and thus some subjectivity/guesswork is common amongst markers. Hence, to argue that hand written exams allow valid and fair assessment of student understanding is misleading, even if that is a common perception.

In summary, this discussion item has elaborated somewhat on arguments for computer based end of year examinations and invites delegates to discuss the merits, demerits and possible future developments in this area. The main arguments put forward are that, apart from substantial efficiency gains for staff so that turnaround times are quicker, also computers are better (objective and consistent) at assessing both computations and interpretations that can be classified clearly. They also port marks straight into university systems thus avoiding manual

handling and adding up. A further core benefit is that they avoid the need to try and read and fairly assess student hand writing.

What is needed now is perhaps a more rigorous study into assessment in general and when and how computer assessment might be considered a satisfactory alternative to a paper based examination? This paper has focussed on foundational modules, essentially years 1 and 2, where the design and evaluation aspects in the learning outcomes are more limited. It would be important to consider the extent to which CAA was able to capture more challenging learning outcomes and open-ended questions as may appear in a 4th year engineering module. The author's viewpoint is to be flexible, even within a single module, that is:

- Use CAA for learning outcomes where it is appropriate and efficient.
- Use alternative assessment types where that is more appropriate to the learning outcomes.

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An Evaluation of Student Learning and Reflection, through the use of an Engineering Project Management Serious Game

Tong, Yao Tite, Caroline N. J.

WMG, University of Warwick.

898969761@qq.com caroline.tite@warwick.ac.uk

KEY WORDS: Serious Game, Learning Outcomes, Traditional Learning Methods, Game-Based Learning Method

ABSTRACT

The research reported is an evaluation of student learning from a student perspective, based on the use of a serious game in project management education. The Project Management Exercise (PME) is a simulation game based around an engineering design, build, test project, and is part of the Project Planning Management and Control module curricula, and delivery is combined with traditional teaching methods. Programme and Project Management (PPM) students in the WMG Department at the University of Warwick reflected on their learning and conducted self-assessment of their cognitive-based, skill-based and affective-based learning outcomes through online questionnaires and interviews. The results of both quantitative and qualitative data captured students' perceptions on learning in the game-based environment. This research provides evidence for the positive learning impact of using serious games in engineering project management education, and includes suggestions for improvements in serious game design and implementation.

INTRODUCTION

Projects are managed in increasingly complex and dynamic organisational environments, and this leads to the need for improved project management education in order to ensure the professional development of students in readiness for the challenge (Thomas and Mengel, 2008). There has been a gap between what effective project management requires, and what project management education provides. Geithner and Menzel (2016) consider that soft skills have been ignored, and that they are difficult to acquire or improve in a traditional classroom setting.

Serious games are an educational solution which create pedagogical transformation of knowledge and skills using a game environment based around a serious purpose (Ma, 2011). There have been many such applications in project management education and a good deal of work based around students' learning have been reported. This study has focussed on learning outcomes by investigating student perceptions based on reflection.

LITERATURE REVIEW

Kraiger et al. (1993) developed a systematic framework of multidimensional learning outcomes, where they were categorised into cognitive-based, skill-based and affective-based. Cognitive-based outcomes were associated with knowledge, while skill-based learning outcomes including the improvement of technical as well as motor skills. Skill-based learning outcomes in this framework were more related to the measurement of stages of learning outcomes such as initial skill acquisition, compilation and then moving to the final stage, automaticity through continual practice. Affective-based learning outcomes include affect, motivation and attitude (Kraiger et al., 1993).

El-Sabaa (2001) developed the "Three-Skill Approach" for project managers and categorised skills 'the best' project managers possess into the following three types:

- (i) Human skills including mobilisation, communication, dealing with situations, delegation of authority,
- (ii) Conceptual and organisational skills including planning, organising, visioning, and strong goal and problem orientation,

- (iii) Technical skills of project knowledge, application of technology, specialised knowledge of tools and techniques, understanding methods, process and procedures.

This model was incorporated in this research by discussing only human skills development in skill-based learning outcomes as conceptual and organisational skills. Technical skills have already been contained in cognitive learning outcomes in the framework of Kraiger et al. (1993).

More recent research in soft skills and project management competencies are acknowledged, for example the 27 Competencies, Association for Project Management 2019. However, the models chosen for analysis were felt to be appropriate for the range of soft skills explored in the context of student learning objectives, and provided a semi-structured approach.

RESEARCH QUESTIONS

The aim of this research was to understand the learning impact of an engineering project management serious game. Work focussed around the following research questions:

- i. What skills are required in Project Managers?*
- ii. How do serious games impact student learning, and how do students perceive this learning?*
- iii. How do serious games enhance Project Management competencies: skill-based, cognitive-based and affective-based?*

METHODOLOGICAL APPROACH

The research sampling field comprised MSc PPM students who engaged in the engineering project management exercise. A quantitative method based around questionnaire responses, using a Qualtrics online tool achieved 77 responses from a cohort of 267 students. The questionnaire was designed so as to encourage students to reflect on their learning during the PME. The questionnaire was also used to investigate how students' learning is enhanced using

a serious game approach compared with a traditional learning approach, and is based on the work of Kraiger et al. (1993) and El-Sabaa (2001).

An online questionnaire was designed to collect quantitative data from participants. The questionnaire was composed of 38 questions (Tong 2019), based around the three different types of learning outcomes categorised by Kraiger et al (1993), cognitive-based, skill-based and affective-based learning outcomes. Students were asked to evaluate to what extent the serious game had an impact on their learning outcome using a Likert scale from 1 (not at all) to 5 (a great deal). At the end of the questionnaire, students were also asked to make a comparison of learning outcomes, between the serious game and lectures, which is referred to a research conducted by Loon et al (2015). The questionnaire was integrated with Qualtrics tool approved by University and it was then be pre-tested to ensure that the questions were easily to be understood. Examples of quantitative analysis results are included in this paper, and qualitative discussion describes key outcomes of the research.

Semi-structured interviews were also conducted with three questionnaire respondents to provide a more in depth understanding of participant responses. Quantitative data analysis included the application of descriptive statistics such as mean, standard deviation and percentage. Qualitative data analysis relied on information being abstracted from transcripts, paraphrasing of themes and summarisation. The statistical results are included in the MSc Dissertation on which this paper is based Tong (2019). Case studies were also used to compare and contrast serious games' learning impact with the findings from this research.

THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

The PME is designed to fill the soft skills gap in project management education. It forms part of a PPMC (Project Planning Management and Control) one week full time module, and students are assigned to project teams according to Belbin's Team Roles (Belbin 2010). The engineering project scenario requires students to plan and manage the delivery of an assembled product within 140 working days, with a budget of £800,000. Teams of five students compete to deliver the final successfully tested assembled product within the timescale and also aim to make £200,000 profit; teams are shown rankings by achievement of profit after the completion of the

game. Teams plan and allocate resources to engineering activities; design, procurement, assembly, test and inspection. They select suppliers for purchased parts and sub-contract work. During the activity, participants manage risks and encounter changes while managing the schedule and budget. Team decisions are delivered to a central simulation model and processed using simulation game software. Game controllers (tutors) assist in facilitating students' understanding of the serious game, by providing a brief introduction and an explanation of game rules at the outset. Tutors offer advice and answer student questions, providing sufficient information to help students make decisions, while allowing students to learn by doing through the process. At the end of the game, each project team reflects on their learning outcomes, and presents these to the cohort of around 30 students. Tutors who control the game provide feedback to each project team, and there is further opportunity for reflecting on learning in post module written assignments.

KEY FINDINGS

Students were asked to reflect and consider their learning based around key project management competencies. The findings were that in addition to project management knowledge, all respondents mentioned learning of soft skills which included emotional management, communication, leadership, organisational and coordination skills. Other unique qualities including charisma, creativity and confidence were also noted. This is in alignment with the literature, in that project management education should not only pay attention to project management concepts, because of the multidimensional requirements of project managers. Respondents also thought that the PME did play a role in their knowledge and skills development and thus helped them meet the more technical requirements for project managers to some degree. Students realised the important role of interpersonal skills in project success. Figure 1 is an example of quantitative questionnaire results, and sets out responses to a question around improvement of team working skills. Interviewees reflected that project team members needed to control their own emotions, to be careful with others' feelings and not to be self-centred, in order to communicate with others effectively and create a harmonious working environment.

Figure 1 Choice percentage of responses related to the comparison of teamwork skills

Question	Level	Choice percentage (%)
To which degree do you believe that PME did better than lectures in the improvement of your teamwork skills?	Not at all	2.60
	Just a little	6.49
	Neutral	14.29
	A lot	51.95
	A great deal	24.68

When asked a series of questions related to learning outcomes, respondents all found this learning experience useful and satisfying, with over half indicating a lot of or great deal of overall satisfaction. As for cognitive-based learning outcomes, the effects of PME on cognitive-based learning outcomes were at the level of neutral or a lot on average. Compared to other cognitive-based learning outcomes, the positive impact of PME on the understanding of project planning concepts was the most obvious. Students showed more positive attitudes toward the effectiveness of PME on cognitive skills than cognitive knowledge. In order to make group decisions in the game process, students needed to see multiple perspectives, weigh the advantages and disadvantages of a decision, and make judgements, which could assist them in enhancing their cognitive abilities.

Positive impacts of PME on communication, teamwork and leadership skills have been identified. However, leadership skills yielded the least learning impact, and this can be attributed to fact that a leader wasn't identified in most teams.

Affective-based learning outcomes explored the perception of students' degree of fun, challenge and engagement in their learning. Figure 2 provides an example of the quantitative analysis of questionnaire results conducted, and in terms of the effect of PME on affective-based learning outcome, and it was considered that PME had the greatest impact on students' engagement due to the highest mean score of 3.92. It was found that on reflection, students felt that engagement in the PME had the greatest impact on learning, with fun and challenge being recognised by students, but to a lesser extent. This is also evidenced by the fact that students normally engage with the PME well beyond the timetabled hours.

Figure 2. Analysis of student responses: affective-based learning outcomes

The impact of PME on affective-based learning outcome [Ⓢ]	The degree of fun [Ⓢ]	The degree of challenging [Ⓢ]	The degree of engagement [Ⓢ]
Mean: μ [Ⓢ]	3.69 [Ⓢ]	3.49 [Ⓢ]	3.92 [Ⓢ]
Standard Deviation: σ [Ⓢ]	0.97 [Ⓢ]	0.91 [Ⓢ]	0.91 [Ⓢ]

Findings showed that most students regarded the PME as a more effective tool in improving their understanding of theoretical knowledge and enhancing cognitive abilities than lectures. Also, most participants agreed that there was a positive effect of PME which led to improvement in teamwork skills, leadership skills and engagement, compared with lectures. From the students' perspective, they reflected that they performed much better in the PME learning environment.

The study explored why serious games were perceived to achieve greater learning outcomes through the discussion of game elements effects. Competition could help improve students' motivational level, while there was a divergence; some participants thought that competition made the learning fun and challenging, and pushed them to achieve the goal, while others stated that instead of feeling pressure from other teams, they focused more on their own tasks. Most students enjoyed working with others and they felt motivated working as a project team. Interviewees reflected that cooperation made them improve their own performance due to the close relationship between personal contribution and overall performance. Also, participants showed their positive feelings of feedback, finding that the real-time feedback could keep them engaged between "a lot" to "a great deal", and in this way improve learning effectiveness. Interviewees were also asked about their perceptions around challenges, including limited time, profit target and unexpected events which led to changes. Although they acknowledged the pressure created by these challenges, they found them quite acceptable, and considered that challenges made the game more realistic and helped them better prepare for future working experiences.

Some areas for possible improvement were noted by students, and these could provide a basis for improvement of the PME, and in future serious game development in the engineering project

management space. The timing of lectures and game sessions could be reviewed to provide the opportunity for students to attend intensive lectures, so that they cover relevant theory prior to playing the game. Feedback could be given to individual teams in small group meetings, before the final debriefing session with the full cohort, where tutors can instead pull out and summarise key points, rather than teams feeding back to the full cohort in detail. Further learning could be achieved by incorporating new and in-depth knowledge into the game. A selection of prior project teams' perceptions and findings from their learning could be incorporated into setting the scene at commencement of the PME, so as to provide a new perspective for tutors and to aid reflection of learning.

Interview responses provided further insights; one participant thought that students' motivational level during the PME continuously increased as understanding and learning grew. Another participant noted that because players had different roles and responsibilities, they would experience different levels of participation and motivation at different stages of the project.

Two case studies were reviewed in comparison with the PME, and the results of comparison are shown in Table 1. The findings are consistent in that serious games have the ability to improve project management knowledge and skills and also students' motivation to learn. The findings from case studies and this piece of work show that Project Management serious games lead to improvement of project management knowledge and soft skills; students regarded serious games as a more interesting and effective learning tool than traditional learning methods. Each research case study was based around similar objectives which were to establish how effective the game-based learning is in meeting learning outcomes. Each of the case studies and the subject of the current work address PM serious games based on authentic scenarios and full project lifecycle, with similar tasks including planning, managing budgets and schedules, managing risks, clear and direct game results.

Table 1. Comparison of case studies where serious games have been used in teaching and learning within the higher education context.

Case studies comparison with current study	Variation with current study	Suggestions for future studies
Effectiveness of learning through experience and reflection in a project management simulation (Geithner and Menzel 2016)	Geithner and Menzel (2016) designed their research to study longer-term learning outcomes through the one-year-later survey. The conclusion showed that gaming learning experience was useful for later work experience and contributed to higher reflectivity.	A follow up with the participants beyond the teaching and learning activity, perhaps a year later, could be used to study learning outcomes through further reflection.
The studies of Geithner and Menzel (2016) and Pariafsai (2016)	The studies were designed to combine the pre- and post-game evaluations so as to measure the skills and abilities development during the serious game learning.	Further work could include pre-game evaluations in order to measure knowledge, and thereby skills development, and changes in students' engagement and motivational level for learning.
Effectiveness of a virtual project based simulation game in construction education (Parifisai, 2016)	This serious game focussed on subject specific education in construction.	Subject specific knowledge development can be built into serious games through subject specific elements being included.

DISCUSSION

Students considered PME an indispensable part of their learning, and they stated that knowledge gained from lectures was closely linked to the serious game experience. Participants reflected that they needed mixed learning approaches, and the combination of game-based and traditional learning approaches formed a particular learning process which allowed students to build on project management knowledge acquired in lectures which laid the theoretical framework. The engineering design, build test project scenario serious game provided a learning environment where they could implement project management tools and methods through applying theoretical concepts covered in lectures, and thereby experience a full project lifecycle.

From the findings, three suggestions for consideration in creating future educational serious games are posited: first, a game controller who provides information and gives targeted feedback and controls the process of the game is preferred over making the game computer based. Second, the positive effects of learning team cooperation and experiencing competition between teams means that multi-player games can affect better learning effectiveness than single-player games. Thirdly, the game could be played more than once by the students, so that they could apply their learning in future serious game scenarios which build from the initial game.

CONCLUSIONS & RECOMMENDATIONS

The results of both quantitative and qualitative data captured students' perceptions on learning from the serious game had affirmative effects on students' cognitive-based, skill-based as well as affective-based learning outcomes. Cognitive-based learning outcomes were apparent; the serious game allowed students to apply theoretical knowledge in an authentic learning environment which mirrors a real workplace, practice the application of tools and methods within the PPM subject area, visualise how the knowledge could be applied in real workplace and then developed their understanding as well as reinforced the knowledge. Additionally, students could practice and develop emotional-related skills in the game process. As for affective-based learning outcomes, learning with the serious game contributed to the promotion of their interests in learning thanks to its fun as well as challenging nature, and the increase of students' engagement.

The game-based learning method was generally found to be more effective and enjoyable than traditional learning methods, from the students' perspective. However, students noted that serious games can be regarded as a complementary learning tool to traditional teaching and learning methods in engineering project management education, and the importance of tutor feedback and guidance is recognised by learners.

From the perspective of the students, the use of serious games has been found to be effective and enjoyable. It helps fill the soft skills gap in project management education by providing opportunities for students to practice these skills related to emotional intelligence, which cannot be easily taught through traditional teaching methods. According to our findings,

students were more likely to achieve improved learning outcomes through the novel serious game with its' interactive learning mode, learning by doing pattern and the relevance to reality.

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Laboratory Experience as an Immersive Pedagogy Tool

Using Virtual and Remote Labs: A Review

Ilyas, Zeshan; Rihawi, Zeina; Azmat, Freeha; Al Sebae, Alaa

University of Warwick

Z.Ilyas@warwick.ac.uk

KEY WORDS: Remote Labs, LabVIEW, Application Optimisation

SUMMARY

Virtual and remote laboratories provide an engaging learning experience, potentially scaled across industries to train students and staff as a cost effective, safe, and interactive alternative to physically handling equipment. A virtual laboratory is a simulation, with questionable model accuracy, whereas a remote laboratory runs on real hardware, thus encountering real errors. Effectiveness and utility of existing remote labs are reviewed using a set criterion through the methodology of a student user experience review. FarLabs was highest rated from the existing pedagogical resources. A combination of virtual and remote laboratory was proposed, merging the strengths of the two. Set in a virtual world, access to communication with other users as well as virtual assistants for purposes of narration, support (educational or disability) and assessment. Embedded into an online learning platform such as Moodle, alongside interactive teaching methods such as H5P, can provide the complete remote university experience. Once developed, applications should be compiled into a national standard database.

INTRODUCTION

Industry demands play a crucial role in determining how engineering syllabi should be structured and delivered (Devadiga, 2017). Given the highly technical aspects of the degree, active application of knowledge within the field is required. This places an increased expectation on educators to deliver fundamental topics pertinent to the course as well as restructure their delivery to involve cooperative and critical learning techniques that empower students to be flexible with their application of theoretical knowledge. Educators are constantly adapting their curricula and restructuring their use of instructional tools to ensure an effective classroom experience.

Authentic learning is clarified as a pedagogical method that aspires to bring the real world closer to students through teaching and learning activities. One of the most recent forms of constructivist pedagogy and provides a more refined framework that homes in on developing proactive problem-solving skills amongst students (Muhardzi et al., 2018). Authentic learning offers another dimension to teaching theories in such that it attempts to make knowledge more accessible to students by requiring them to utilize learned theories in a vast range of real-world scenarios.

Virtual laboratories are web applications that emulate the operation of real laboratories and enable students to practice in a “safe” environment based on approximate models developed, whilst remote labs retain the safety benefit, they also provide real data with real errors as actual equipment is utilized (NMC, 2019). Collected data can be shown in visualisation such as Figure 1 below. Remote labs have developed significantly in the 21st century, to provide a realistic laboratory experience, for distance learning students. System applications for this can be scaled across industries to train staff as a cost effective, and interactive alternative to physically handling equipment in a laboratory.

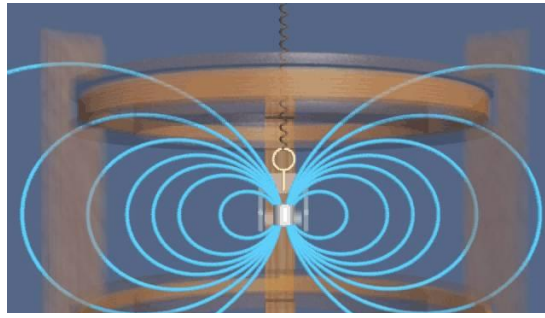


Figure 6: Visual representation of measured data shown as part of MIT remote lab (MIT, 2019)

LITERATURE REVIEW

- *Traditional in-situ Laboratory*

This typically involves a student following a set of instructions to conduct a study on the physical equipment provided, to achieve the learning objectives set. The main problems for companies such as *Warwick Manufacturing Group (WMG)*, providing high calibre degree apprenticeships, is the lack of interaction and time with apprentices, and as such, may not experience the full benefits of a laboratory in comparison to a university experience. Alternatives need to be investigated. Early solutions to distance learning, consisted of student performing laboratory exercises at another institution or spend an extended period on the engineering campus in a concentrated laboratory course, with a conventional style of delivery. Other solutions were kits to use at home (Feisel & Rosa, 2013).

- *Virtual Laboratory*

Simulations emulate the operation of real laboratories and are primarily used to provide a pre-lab experience to become familiarized with the experiment, improve key skills and predict the outcome before performing the experiment in real. Virtual labs can substitute for physical lab exercises. More recently, 3D virtual reality (VR) experience laboratories are being developed to provide immersive experiences of laboratories. Unity, a multi-platform game engine, is a popular choice among developers for its support and content (Gonzalez et al., 2017). Tutorials can be found abundantly as well as guidance on the code itself e.g. C# support forums. With increasing accessibility to VR equipment, as well as greater access to VR content, integration of

such an activity into the academic syllabi/training is likely to increase in popularity as a way of including technology to make delivering education interactive and enjoyable.

- ***Remote Access Laboratory***

A virtual laboratory is a simulation, with questionable model accuracy, whereas a remote laboratory runs on real hardware, thus encountering real errors. The hardware will be like what is used in a hands-on laboratory exercise, with one major difference. The experiment must be remotely reconfigurable. One of the key benefits of remote labs is the degree of safety from potential hazards that may be apparent when dealing with real equipment. For example, certain demonstrations may be deemed too dangerous for the user to educate through traditional norms, however, through virtual or remote learning, this is no longer a problem. For a remote lab, the risk remains for the organizer, although they are better trained to handle such situations.

An important part of a remote laboratory is the ability to control and configure the experiment remotely. In early remote laboratory systems, a popular choice was the *NI/LabVIEW* hardware/software solutions (Ertugrul, 2000). Measurement data needs to be digitized and transferred through the internet to the user and presented in the user interface. The hardware for digitizing the measurement data varies depending on several factors, such as frequency of the signal to be measured, amount of data to be sampled, and type of signal.

Table I shows a summary comparison of various laboratory types detailing various features.

Table 2: Summary comparison of laboratory types

Feature	Traditional in situ	Virtual Lab	Remote Lab
Close to feeling "real"	No true replacement for real experiment - High	Completely virtual - Low	Very close to reality – Reasonably high (if camera included)
Responsiveness & control	High	Reasonably high	
Support	Lab technician & office hours	Students can email questions. Pedagogical assistants or wizards may be built in alongside other assistance features.	
Freedom of configuration & variance	Experimentation with open approach possible. Limited by lab facilities.	Limited by programmed possibilities	Limited by pre-configured options
Supervision	Lab assistants	Email enquiries and discussions using chat software	
Access times	Limited to academic timetable	Limited by setup configuration	
Access limits	Time limited if rolling lab periods – no second chance	No limits; queued access when other users are completing experiments	
Progress check	Submitted reports	Performance reports, laboratory results & formative assessments	
Relative cost	High	Low	Medium
Data	Realistic	Idealised	Realistic
Health & Safety	Assessments required; precautions put in place	No physical hazard for user / cyber-bullying in virtual platforms	
Maintenance	Equipment	Software update	Equipment and software update

CONTEXT: THE PROBLEM AND INTERVENTION

The goal was to find the most effective existing remote lab and find ways to optimise the system based on feedback. A set of 22 students were selected from various disciplines, majority of which were graduates of science related degrees, and were presented with a set criterion alongside several open-ended questions. A quantitative rating was assigned ranging from 1-10 whereby 1 is equivalent to poor and 10 is equivalent to an excellent for the respective criteria. For each laboratory, the theory was first looked upon and then the laboratory exercises were completed, and results exported for storage. Students were given login details for two selected

labs based on performance in the user experience review and were tasked to randomly complete a laboratory from each source. Typically, a laboratory was completed in approximately 20 minutes, however, some students did spend more time looking through the available content. The following were additional questions required for response:

- Were the laboratory aims met?
- Did you enjoy the experience, and what aspect specifically?
- What would you change to improve your experience?
- Would you use this in future / recommend to a friend?

EVALUATION OF INTERVENTION

A total of 6 existing laboratories were assessed, such as shown in Figure 2. An independent review is initially carried out, from which two are selected for a student experience review. A model is proposed (Nickersen, et al., 2007) for systematic testing of the educational effectiveness of a given remote lab. The following factors are evaluated:

1. Suitability to accomplish the learning objectives.
2. Support for social coordination.
3. Capability to accommodate student's individual differences, e.g., to consider the student grade level, cognitive style, psychological development etc.

DISCUSSION

Table 2 shows the results collected from the user experience review of various remote labs, highlighting the success of FARLabs with the participants.

Table 3: Summary of user (and student) experience of remote labs (1: poor, 10: excellent)

Criteria	Remote Lab Rating					
	iLab	OpenScience	LiLa	FARLabs	LabWorks	PV Lab
Accessibility / ease of use	4	6	3	8 (6)	7 (5)	5
Features & Flexibility	6	6	4	7 (5)	5 (5)	8
Live video	No	Yes	Few	Yes	Yes	Yes
Manual, supporting material & theory	5	7	4	9 (8)	8 (7)	7
Data presentation & retrieval	6	7	5	6 (7)	6 (7)	6
User assistance	4	5	4	6 (6)	7 (6)	6
Visual appeal	3	6	3	7 (5)	6 (4)	6

From the reviews above, it can be concluded that in order to produce an effective and engaging remote lab, the client application needs to be optimised visually to reflect a real sense of the laboratory as well as finding the balance of simplicity in use and flexibility in control. One way to improve the study would have been to conduct theory tests before and then check understanding of the topic upon completion of the laboratory. In addition, the scope was limited by only selecting to evaluate two through the student review. Lastly, not all students did the same laboratory from the sources therefore some may have been designed better than others. *LabVIEW myRIO* is recommended as a starting point, with easy access to additional features and plugins, developers can utilise the software to design a successful remote laboratory. Starter courses such as Core 1 and Core 2 can be completed as tutorials online, with useful exercises in addition to the *NI myRIO Project Essentials Guide*.

Using the *HPIB IEEE 488* standard protocol instrument drivers, control of instruments remotely is possible (Feisel & Rosa, 2013). Using the *NI myRIO Embedded Kit*, *DAQ Assistant Express* is used to acquire data and once placed on the block diagram in *LabVIEW*, a configuration window opens to setup measurement parameters. *Internet Toolkit* publishes a *Virtual Instrument (VI)* to the internet and provides a link for access from anywhere. This grants only one active connection at a time whilst a second person would join a queue. *Database Connectivity Toolkit* can be utilized to connect lab fields to a database and save student information, as well as, allow students to submit results online (Baradaranshokouhi & Rossiter, 2019). While students can generally carry out the experiments at their convenience, some labs require them to book and reserve time for their experiments, especially since there are usually many students trying to perform the same experiments at the same time (Mendes et al., 2013). Methods need to be

developed such that the same lab equipment can be used by multiple users to produce different results, therefore negating the need for strict lab scheduling.

As remote labs are readily available through the web browser, access through mobile application should be developed. Support for mobile browsers should be essential, with development of applications of remote labs (or general platform) downloadable from services such as *PlayStore*. A UK national standard database of available remote laboratories should be compiled whereby universities can share resources, and thus reduce cost.

Third party developers (Callaghan, et al., 2017) can create voice experiences/custom skills that extend the capabilities of any Alexa-enabled device using the Alexa Skills Kit (ASK). User created custom skills have a request name which is a key word used by the end user to initiate a set of voice interactions/responses with the Echo device. In addition, this feature could be vitally used to develop consideration for disabilities (Duarte & Butz, 2001). Using an existing laboratory as a starting point, the next step in the process is to create a structured series of interactions suitable for a voice driven experience which includes an overview of the laboratory, access to help, control and configuration of the instrumentation and circuits in the hardware layer, assessment and feedback to the student (Harvey et al., 2016).

Each kind of laboratory has its individual assets, thus, the challenge is finding in what way to combine both labs to achieve specific learning outcomes (Heradio, et al., 2016). Laboratories should be made available on the online learning platform in use such as *Moodle* and provide a complete interactive experience of teaching through *H5P* interactive video as way of delivering content (Kolas et al., 2016). Socio-constructivist theories argue that learning is a constructive and collaborative process (Joolingen et al., 2005). Learners undertake experiments to discover relationships between phenomena, and construct models to express their understanding. Thus, learning activities are more constructive by nature than, for instance, listening to lectures or solving textbook problems. According to socio-constructivism, task performance should if possible, occur in partnership with peers, and it should be structured by the learners (Fernandes et al., 2019). Virtual worlds can create a realistic ambience and provide a platform for realistic communication among users even allowing for “face to face” interaction by means of avatars (Callaghan et al., 2013).

CONCLUSIONS & RECOMMENDATIONS

Remote labs have developed significantly in the 21st century, to provide a realistic laboratory experience, for distance learning students. Applications for this can be scaled across industries to train staff as a cost effective, safe and interactive alternative to physically handling equipment in a laboratory. This report has evaluated the effectiveness and utility of existing virtual and remote labs to provide a review for future design of an optimised remote lab for education through the methodology a student user experience review. *FARLabs*, developed by the Australian government, was amongst the highest rated remote labs found. The main strengths were its availability of support content and holistic lab experience including formative assessments to test progress. A realistic client is essential in developing an effective lab for education. The most typical software used was *LabVIEW*.

A combination of virtual and remote laboratory was proposed, merging the strengths of the two. Set in a virtual world whereby communication with other users is possible, as well as possibility of developing virtual assistants for purposes of narration, support and assessment. All of which embedded into a learning platform such as *Moodle*, alongside interactive teaching methods such as *H5P*, can provide the complete remote university experience. Lastly, once developed, it is essential that applications and design configurations are shared among different institutions to speed up establishing remote labs as a viable alternative to a physical laboratory experience. Further research should be conducted in finding a standard method of evaluating the effectiveness of the correct balance of remote and virtual laboratories.

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The Significance of Simulating “Serious Play” in Teaching Innovation

Ahmad, Ali, J.

WMG, University of Warwick

Ali.Ahmad@warwick.ac.uk

KEY WORDS: Simulations; Pedagogy; Innovation; Learning; Lego

SUMMARY

I teach postgraduate students and corporate nominees the subject ‘Innovation’. Innovation is taught in a module, comprising approximately 40 contact hours, spread over a week in the 0900-1830 format. This format allows for an extended amount of ‘facetime’ with students and enables me to design sessions around specific topics linked to the module’s learning outcomes (LO). One important LO is to “practically demonstrate innovation management skills in a physical simulation group project”. I have designed a simulation using Lego Mindstorms as the main teaching technology in order to give students a chance to “see” and “feel” the challenges of “doing” innovation in a “playful” way. As a facilitator, I adopt a coaching and mentoring-influenced teaching and feedback style, helping students gain experience in a controlled and condensed cross-section of the ‘as-real-as-possible’ conditions for *doing* innovation and entrepreneurship. The aim is not to give students readymade ‘answers’, but to highlight potential mistakes, plant seeds and point them in the right direction. The importance of play is widely approved in the associated pedagogic literature and students are exposed to the notion that if one were to study the history of the development of most new innovations - whether scientific, technological or business – one would find that the subject “innovator” stumbled on to something new while “tinkering” or simply “messing around”. The aim is to give students an opportunity to deploy their creative energies, work together collaboratively and solve a “serious” commercial / industrial problem by guising the learning experience as “serious play”.

INTRODUCTION

My teaching philosophy is based on my epistemological worldview on eligible routes to knowledge and skills acquisition. It is also based on my experiences in class. I am a member of Enterprise Educators UK (EEUK) and attend their events regularly which highlight best practice in entrepreneurship education in the UK. Entrepreneurship education best practice is captured within UK QAA's guidelines on teaching entrepreneurship, aspects of which I have introduced within the Innovation module and have discussed at EEUK events with academic peers to elicit feedback for improvement. For example, I have embraced the UK-QAA definition of entrepreneurship education which highlights that there are clear differences in teaching "about" and teaching "for" Innovation and entrepreneurship (I&E) (UK-QAA, 2018). Both aspects are important; within the teaching about I&E view, courses are expected to remain high level and conceptual, where the aim is to engage students in scholarly debate by drawing on published literature, thereby, developing theoreticians or researchers. I embraced the UK-QAA guidelines for the Innovation module such that I would be teaching for I&E – which is entirely different.

In the module, students are exposed to concepts such as trial and error, effectuation, creative thinking, understanding and breaking down problems; topics that are linked to learning "about" innovation. I wanted to design a workshop that would enable learning "for" *doing* innovation – which is entirely different. Bridging the "for" and "about" gap, to me, was essential for closing the learning loop. It is one thing to read about, listen to and discuss risk, uncertainty, project management, budgetary controls, opportunity evaluation – but an entirely different thing when actually "feeling" the pressure that comes from taking personal risks or taking risks on behalf of a team whose members are relying on you to get things right, to effectuate solutions to problems as they arise in real time and so on.

The adherence to the teaching *for* I&E guidelines proposed by the UK-QAA comes via the development and adoption of simulations. Depending on the delivery format and the profile of the participants, I use an original physical simulation I have designed based on Lego Mindstorms. The simulation's design ethos was informed by known retention issues. Most students, after about a week post a module, have retained, at the most, between 5-8% of the content. The rest of the content usually fails to influence thinking or to create future recall to influence managerial or entrepreneurial behaviour. Amongst other factors, the problem of retention has to do with

human attention spans, which start to taper off after 15 minutes of System 2-type intensive learning (Biggs & Tang, 2011). What if I could design an *immersive* and *fun* learning experience, the outcomes of which could be easily recalled even after multiple years had gone by? I looked back into my own educational history and thought to myself; the learning from which experiences at university did I recall the most? Which experiences casted a lasting impression and made me think later on in professional life when I was taking real-world professional decisions? The simulation has the right ingredients – students would work together in a group to tackle a particular (commercial / industrial) problem through the medium of *play* to create something physical and original – new to the world. They wouldn't forget their Lego creations and the solutions such creations had the potential to provide (if built) to industrial partners.

LITERATURE REVIEW: PEDAGOGIC RATIONALE

The 'Innovation Masterclass' simulation has been designed by keeping in view a number of important pedagogic principles. First, Neck et al. (2014) in their seminal text "Teaching Entrepreneurship: A Practice-Based Approach" make the case that teaching Innovation and entrepreneurship (I&E) differs from teaching other "business" subjects such as accounting, marketing or strategy. Traditional business subjects have vast bodies of literature, and scholarly traditions are well developed to the extent that tutors can safely remain at the purely conceptual level, explaining scholarly dis-agreements and theoretical advances. Whereas, for I&E, the task of the educator is different – they are expected to unleash the "innovative potential" and "entrepreneurial spirit" of their students and produce *practitioners*. Such students are then expected to be able to start businesses, give serious consideration to self-employment as a career and practice innovation as intrapreneurs (Kuckertz, 2013). Hence, what follows is a belief that the I&E educator should demonstrate an entrepreneurial orientation within themselves – be, as Hannon (2018) – a powerful voice in entrepreneurship education, emphasises, an 'entrepreneurial educator'. The simulation, therefore, had to enable students to be able to exercise their I&E potential in a way that allowed self-discovery and the inculcation of the known I&E skillset.

Second, the importance of "play" as a valid means of teaching doing innovation was considered. The importance of "play" is acknowledged and widely approved as a pedagogical approach by

its proponents Piaget, Vygotsky, and most notably the influential Seymour Papert. My conviction is that learning is most effective when it's student-led, cooperative, and grounded in authentic contexts that heighten learner agency and engagement. This 'social constructionist' approach is intended to foster learning by making, learning by doing, and embodies experiential learning in order to help my students develop critical and creative thinking skills. I believe this approach works because my students are able to extend their knowledge and skills by designing solutions to real-world business challenges. This is precisely the sort of creative experimentation, iteration, and exploration that Papert labelled "hard fun" (Papert, 2002).

DESCRIPTION OF INTERVENTION / PRACTICE

The simulation commences with a 15-presentation on "Autonomous Vehicles". This presentation is meant to pump-prime the students on the potentials of robotics and AI as applied to the domain of personal and public land transport. After the presentation, the workshop's background is explained by myself as follows:

An automobile company (like Jaguar Land Rover or Toyota) with a diverse range of vehicles pitched at different market segments is finding that it is slipping in to the typical trough of slow growth and low returns from its existing range. The management believes that a new market opportunity exists in the goods transport sector: road convoys - where a fleet of vehicles travelling over long distances can follow a lead vehicle, braking and accelerating, thereby travelling as a convoy. To proof this concept, the management has assembled five multi-disciplinary teams within the organization. You are part of a team invited to pitch your proof-of-concept along with its business case to the management.



Figure 1: Students getting accustomed to Lego Mindstorms and planning their day

I then proceeded to explain that each team (which I created prior based on my assessment of student personalities during the previous 4 days of interaction), in competition with others was going to have to demonstrate two outcomes (as under). I also introduced an element of cooperation – because a convoy is based on multiple vehicles and each team had to collaborate towards to the end to ensure that the convoy ‘worked’ – one team’s output’s failure had the potential to jeopardise the entire convoy.



Figure 2: A team pitching their 'product'

Therefore, working cooperatively (competitive + collaborative), each team needed to demonstrate that:

1. Their 'proof-of-concept' works; demonstrating the same independently and as a part of a convoy
2. They have a strong commercial case backed by real world market research on a particular customer (how will that particular customer save money or generate a new income from 'your' innovation?).

Teams were cautioned: 'management' requires that the following be adhered to:

1. Investment in the project is capped at £500
2. Deadlines must be met as per schedule, no extra time will be given under any circumstances
3. Team Presentation must last 10 minutes



Figure 3: A discussion around how best to create the product's business case using innovation tools

Each team has typically 6-7 members and are advised to choose a team leader. They were assigned a working space – a separate syndicate room and a desktop with the programming environment pre-installed. Within the team, students were to take on one of the following functional roles:

1. Commercial Research & Case Development
2. Finance
3. Physical Design & Assembly
4. Software Design & Testing
5. Manufacturing
6. General Management

Teams are required to develop a budget and keep track of their expenditures in the following areas:

1. Technical advice - @ £10 per-minute
2. Business consultancy - @ £10 per-minute
3. Parts and materials - @ £1 per-component (Lego piece)
4. Manufacturing - @ £1 per-minute of factory time (at actuals)
5. Programming - @ £1 per-minute
6. Testing - @ £5 per-minute

Presentation requirements were provided along with the workflow and deadlines as per the following scheme:

1. Attending a de-briefing by their organization's Board of Directors (BoD)
2. Pitching an initial design concept, along with the its commercial potential to the management. The management at this stage will monitor the project's budget, parts sourcing, manufacturing, assembly and testing strategies. The team must secure BoD buy-in and approval at this stage.
3. Produce product and presentation
4. Test the prototype
5. Demonstrate the prototype
6. Present new product concept to the management

Students are required to manage their own time – they are free to take breaks for tea and lunch whenever they wish – keeping in view their own task completion time lines. I also knew students would ask questions about the assessment. I made the entire criteria and my assessment template downloadable via Moodle. Assessment was undertaken at three stages – once at point 2 above (at 1230), and then points 5 (1530) and 6 (1630). The weightage is 20% to the output and 80% to the process with criteria to judge performance on various parameters linked to effective innovation management. Background to the intervention / practice (this can include both learning and teaching in the classroom or lab as well as work-based learning and outreach activities)

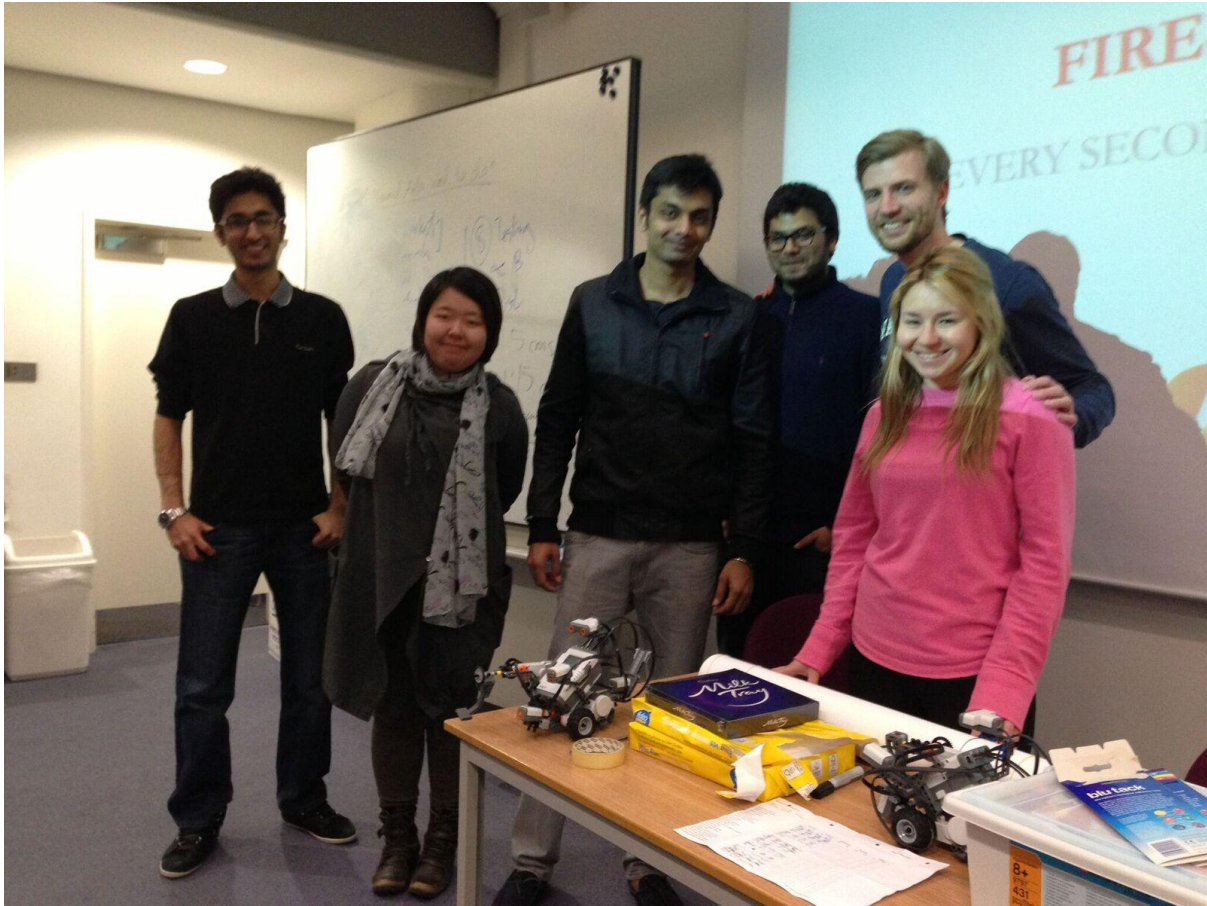


Figure 4: A student team posing with their Lego creations during post-session reflections

EVALUATION OF INTERVENTION / PRACTICE

Student feedback which been very positive – for example, out of the 84 module evaluations received in 2018-19 – 18 flagged the Lego-based simulation in response to the question: “What elements of the module did you find the most informative?”. A useful critique was received as well; the student respondent stated:

*“The Lego Mindstorms challenge on the final day was very fun and a great exercise to bring together various aspects of a project that required different roles to be performed simultaneously. **However, it was quite difficult to see an obvious connection between it and the material that had been taught during the previous 4 days [emphasis added].**”*

The above denotes the problem of disconnect between theory and practice – what has been learnt in class is a stripped down and simplified version of benchmarked industry tools and methods. When these tools are applied by students, a majority of whom are undertaking a masters degree straight after an undergraduate degree, to “real world” situations, even in an educational simulation can be overwhelming for some. Tool-specific expertise, professional work experience and a good working knowledge of commercial and industry norms is needed to do ‘exceedingly’ well; however, the simulation experience is designed such that anyone who has attended the module can do, if they follow instructions and are engaged, ‘very’ well. I have now refined the morning de-brief and let the students know that *doing* innovation is far more difficult than learning *about* innovation; that failure if it occurs is a part of learning and is an essential part of trial and error.

External validation on the simulation has been received by Lego Education UK, who assist me in running it. An experienced Lego Education trainer joins me for the full day to assist with delivery. Recently, a pedagogic expert from Pi-Top UK (a learning technologies provider and Lego Education partner) observed my delivery of the Masterclass over the course of a full-day. Based on the expert’s feedback, Pi-Top UK commissioned me to contribute a chapter to their publication which is widely circulated within the international HEI sector explaining the pedagogic rationale behind the Masterclass (Ahmad, 2019).

DISCUSSION

Since 2013, the Simulation has gone through two major updates – it is now based on the Lego Mindstorms EV3 platform. Many minor refinements have been made over the years to streamline the overall learning experience. These have been based on student feedback, peer observations and my own reflections. Simple refinements such as advising students to pre-install the Lego Mindstorms software on their laptops a day before, providing a budgeted vs actual template, a Gantt Chart format with critical deadlines plotted, ensuring batteries are charged prior and double checking whether the disassembled materials are kept back as per the kit boxes’ formats have allowed students to take back more from the workshop in terms of new learning.

One thing that did cause serious problems was the shipping of the kits to WMG's overseas centres. The kits got stopped at customs, duties had to be paid and when they finally arrived, we found them opened and rummaged with. It took countless hours reconciling them and double checking whether all components were in place for students to use. Since though, WMG's partners have invested in their own kits. I also found that if students were given a carte blanche to think up any product to solve a hypothetical problem for any industry – problems arose. Ideation took too long and was quite unstructured, the build-off became overly complicated and the level of programming expertise needed to make the product work couldn't be developed in a matter of a few hours – especially since most students had no prior experience with coding.

The first version of the workshop was focussed on a very 'specific' product and industry – which made the 'process' and 'outputs' regimented and confined. The second version was too broad so as to make the 'process' too unpredictable and risky and the 'outputs' incomplete and invaluable. The current EV3-based version is based on the 'anthropic principle' and is about staying in 'goldilocks' or 'just right' zones when it comes to delivering an impactful and memorable learning experience. By giving students examples of what previous teams had developed, I am able to provide a reasonable level of confidence to students right from the onset that the task ahead for them is 'achievable' and that they are not purposefully 'set up to fail'.

CONCLUSIONS

Learning technologies like Lego Mindstorms are only useful as pedagogic tools when the tutors who deploy them are forward thinkers and reflective. A critique of the simulation experience from a pedagogical perspective is the problem of student 'team formation'. A number of approaches have been used to form student teams, such as mere random allocation / allocation based on demographic details / allocation based on tutor knowledge of student 'personalities'; however, none of these are 'ideal' and have led to student feedback highlighting negative team socializing experiences.

Random allocation is justifiable only on the grounds that 'in the real world you don't always get to choose who you work with' – however, this 'ground' is swiftly disappearing in the 'real world' as well. Tools like "Insight" and Belbin's much updated online platform are now used in leading

corporations to profile employees and use such profiling to create optimised teams. Demographic profiling has its limitations too; age, gender and nationality are not suitable guide variables for determining 'team-based character'. Finally, tutors' assessment of student 'personalities' can be inaccurate; personal biases such as stereotyping or mis-reading behaviour due to cultural differences and language barriers cannot be entirely discounted.

Hence, what is needed is a pedagogically valid tool – one that has been shown to be reliable, which is conveniently deployable, to profile student personality types and to allocate the profiled students to optimised teams. By optimised it is meant that such teams are configured to undertake the task at hand – not run a police operation or undertake a forensic accounting audit. The contention is that even if the profiling and allocation exercise using such an approach is not wholly accurate all of the times, for those instances when students do experience negative team socialization experiences, there is present an evident explanation for why the teams were put together in the way they were.

RECOMMENDATIONS

It is important to consider return on investment – the kits are expensive, think about how frequently they will be used and for how long. Can you perhaps use something less complicated and cheaper like Meccano or Scalextric? If not integrated properly into the curriculum, Mindstorms-type learning technologies can produce blow-back which might ultimately lead to negative student feedback.

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‘Exit through the Workshop’: The Use of Escape Rooms as an Alternative Teaching Method in Engineering

Evans, Chris, Schrock, Lauren, Andrews, Jane

WMG, University of Warwick

c.l.evans@warwick.ac.uk

KEY WORDS: Escape Rooms, Engineering, Induction

SUMMARY

Escape rooms are a popular form of entertainment that have in recent years, begun to draw the attention of educators. However, studies of serious escape rooms have tended to focus on the development of soft skills rather than learning per se. This paper reports on the use of educational escape rooms within engineering education at a higher education institution and provides insight into the instructional effectiveness of using educational escape rooms as a methodology for teaching engineering (Savage et al., 2011). In particular, the use of an escape room as a student induction activity is examined as an alternative approach to critically solving and understanding key engineering problems and concepts.

INTRODUCTION

As ‘Digital Natives’, today’s students present a challenge to educators who often experience difficulties in keeping students motivated and engaged through conventional taught learning (Fotaris & Mastoras, 2018). Engineering students are no exception. A recent study into the motivation of engineering students in higher education suggests that the practical application of authentic, real life problems presents one of the greatest positive impacts on engineering students’ intrinsic desire to learn (Savage et al., 2011). For these students, games or simulations in particular have the ability to engage players in complex meaning-making contexts mirroring real-world scenarios (Fabricatore et al., 2019). Authentic learning typically focuses on real-

world, complex problems and their solutions, using role-playing exercises, problem-based activities, case studies, ways of working, and community (Hedhiana, et al 2018). Escape rooms, it would appear, encapsulate the essence of authentic learning . Indeed, in his discussion paper on the subject, Nicholson, (2015) describes Escape Rooms as “*live action role-playing*” (P.g 4) whereby “*...players discover clues, solve puzzles, and accomplish tasks in one or more rooms in order to accomplish a specific goal (usually escaping from the room) in a limited amount of time*” (Pg. 1)

Escape rooms fall into a non-digital game-based genre of learning that has certain advantages over its trendier digital counterpart; it is more cost effective, it has a lower administrative overhead, and it provides a greater opportunity for enhanced social interaction. Furthermore, a game-based learning experience can result in increased attendance rates, higher levels of enjoyment and a more interesting learning experience (Barata et al., 2013).

Game-based learning incorporates gaming technologies and techniques into the learning process with an aim of creating a fun, motivating, and interactive learning experience that promotes student-centric learning. Unlike traditional lectures, game-based learning can be balanced to suit the learners’ individual skill level, preventing them from becoming frustrated or bored and facilitating ‘flow’, a state of optimal experience for learning (Mao et al., 2016). For engineering students, there is the additional benefit that sees games centred on simulation gameplay mechanics functioning as micro-worlds, and thus providing the additional essential characteristics of intrinsically motivating learning environments (Rieber, 1996).

RESEARCH QUESTION

This paper explores the potential of using escape rooms as a means to teach engineering skills, and in particular: “***In which ways can escape rooms be used to facilitate authentic learning within Engineering Education?***”

EDUCATIONAL ESCAPE ROOMS

Escape rooms are physical adventure games in which players work together to solve puzzles using hints, clues and a strategy to escape from a locked room. Escape rooms have flourished

in the last decade as a way to develop transferable employability skills (Richert *et al.*, 2016), such as soft skills including teamwork, communication and multitasking (Borrego *et al.*, 2017; Clarke *et al.*, 2017; Zhang *et al.*, 2018).

Escape rooms are also an exercise of knowledge and critical thinking since students may apply their knowledge of a subject to new situations, and analyse information in order to solve problems in these new contexts. Hence, escape rooms have started to appear in education as a revision exercise in order to solidify prior learning (Dietrich, 2018; Vörös & Sárközi, 2017). There are many potential benefits realised within this experiential learning environment, as summarised in Table 1, below.

Table 4: Advantages of Educational Escape Rooms (Fotaris & Mastoras, 2018)

Advantages	Studies	%
Teamwork/Collaboration	28	41.2
Enjoyment	26	38.3
Engagement	22	32.4
Learning Gain	21	30.9
Motivation	20	29.4
Social Interaction	19	27.9
Critical thinking/problem-solving	11	16.2
Leadership	7	10.3
Creativity	7	10.3
Reusability	7	10.3
Revision Method	7	10.3

Nevertheless, there is still little empirical evidence on the use of escape rooms as a method for learning rather than as an exercise to develop soft skills or to reinforce learning. Further, there is a gap on the use of escape rooms in the specific discipline of engineering.

IDENTIFYING LEVEL OF CONTENT DELIVERY BY ESCAPING THE ROOM DURING INDUCTION

In seeking to address the gap in knowledge, this study builds upon a small but growing body of evidence that recognises the motivational and pedagogical benefit of educational escape rooms (Clarke et al., 2017). Following an Action Research Methodology (Norton, 2018), a series of trials will be put in place during the undergraduate induction period. First year engineering students will work in teams of between five and seven in order to solve a series of mathematics, physics and electronics problems. The primary objective of the escape room is for students to solve a series of realistic engineering problems to allow course leaders to assess student's existing knowledge. The problems are modelled upon the principles of constructivism (Bada, 2015), that is, enabling students to construct knowledge and meaning from their active experiences. Indeed, the perceived benefits of constructivist learning may be particularly valuable where the teaching of complex skills, such as problem solving or critical thinking skills (Tam, 2000). Furthermore, presenting these problems to the learners' at an early stage will inform the tutor of the students' existing knowledge and experience and subsequently aid the tutor in their understanding of the students' needs and abilities. These activities, co-created with the tutors, are aligned to the module outcomes (Biggs & Tang, 2015) and reflect closely the subject matter delivered within the first lessons.

So for example, in the module '*Electrical and Electronic Circuits and Devices*' the students will be taught the difference between circuits in parallel and series. The associated room escape problem that the students will need to overcome can be seen in figure 1 below. When this particular problem has been solved, the solution will be presented to the facilitator who will provide an additional clue... or a time penalty if the answer is wrong.

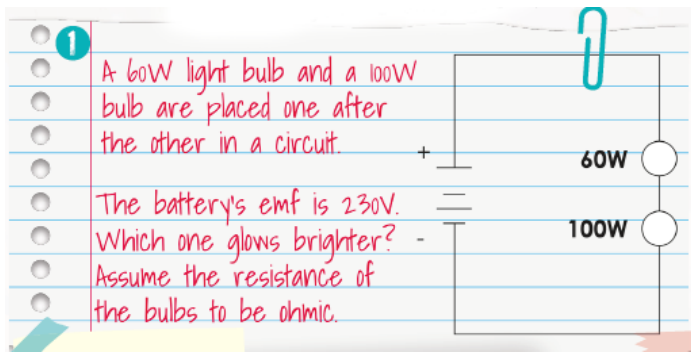


Figure 7: Electrical and Electronics Circuits and Devices Puzzle

Once the game has ended, there is a 15 minute debriefing session where the science is explained, and for each puzzle, the students have the opportunity to explain how they arrived at their particular solution.

ESCAPE THE ROOM: A GUIDE TO PLAY

- Set up

The action takes place within a single room, with students, divided into teams of between five and seven, and competing against the clock and against the other teams. The team that escapes the room in the least amount of time is the winner, though there is a maximum limit of 45 minutes. The problems are designed to be challenging, and for that reason, a mechanism to prevent teams from becoming stuck on a particular problem and therefore becoming frustrated and disengaged, is required. Differentiation and support is managed by allowing teams to buy clues, which incur a time penalty, but ultimately facilitate flow (Csikszentmihalyi, 1990) and constructivism. For example, the clue for the electrical problem described in figure 1 reads: “The bulb with high resistance and more power dissipation will glow brighter”. In this instance, the students should remember how ohm’s law works for circuits in series and apply the logic provided within the clue.

Please note that the students are not actually ‘locked’ in the room; rather the endgame requires them to identify the correct key in order to ‘escape’.

- **Story**

The room escape experience inhabits the fictional world whereby two mad professors have locked the students in the room. These characters have unique personalities, represented in the opening instructional video, in print form and in person by the facilitators, dressed in white coats and acting out their specific roles within the story. Narrative forms an important element of the learning process as it helps the learners' to interpret the world while also providing a unit of meaning that stores and permits retrieval of experiences within that world (Bruner, 1985).

- **Method**

The basic premise is to escape the workshop before time runs out by solving puzzles. Each room is monitored by a member of staff acting as one of the narrative figures to check puzzle solutions, provide hints should students buy them with time, and deduct time from the game should the team answer a puzzle incorrectly. The puzzles are real-world problems that are representative of exercises expected within the first year syllabus of an engineering undergraduate degree.

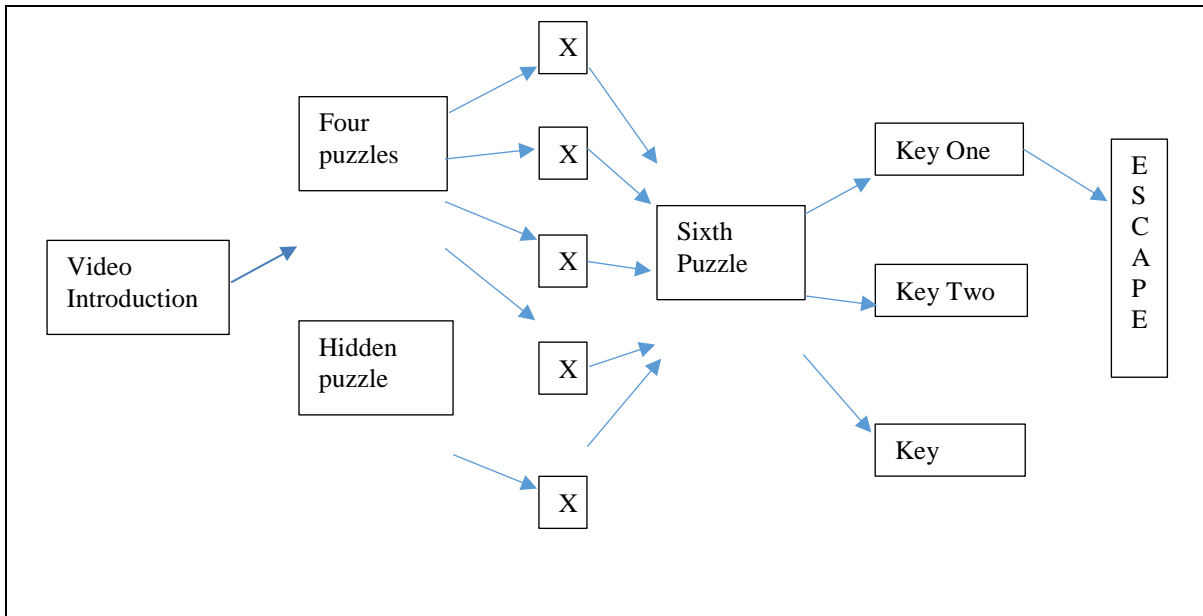


Figure 8: Puzzle flow and dependencies

POST-GAME REFLECTION

It could be argued that a higher level of learning takes place within the post-game period of reflection and explanation, compared to the playing of the game itself. This is because experiential education more than learning by doing. Experiential learning occurs when individuals engage in a concrete activity, reflect upon that activity, and develop a new understanding that can be transferred to other situations. At the end of the game, students deconstruct how they played, won and lost, and arrived at each particular answer.

EDUCATIONAL IMPACT

In analysing the use of escape rooms in engineering education, the study also considers the pedagogical implications of failure to escape the room and how failure may be translated into a positive learning experience. The educational impact of the work will be evaluated using quantitative and qualitative techniques so as to provide a substantive debrief (Sanchez & Plumettaz-Sieber, 2019). Of particular interest is the attention to student's perceptions of the impact that any pre-requisite knowledge had on the activity, such as puzzles or engineering concepts that the students found particularly challenging. Lastly, it is anticipated that this study will provide an understanding of students' perceptions of the use of escape rooms as an alternative approach to teaching and learning, both as a method of soft skills development and beyond. Whilst this is very much a work in progress, it is anticipated that the study will demonstrate that escape rooms represent an engaging and pragmatic way to induct students into university curriculum.

The study will contribute to the body of knowledge in the areas of education-based games and engineering education in a number of ways:

1. Evidence the pedagogic value of escape rooms with regard to evaluating student's prior knowledge.
2. Analyse how escape rooms can contribute to a positive transition into engineering education for first year students.
3. Critique how escape rooms enable the early development of transferable employability skills, particularly in the area of team working.

4. Teach students from the onset of their degree how to learn from failure in a way that is non-threatening and experienced within a safe and positive environment.

INITIAL EVALUATION AND DISCUSSION

The escape room has been play tested with staff and piloted with both BSc and MSc students during their Induction. Feedback on the difficulty of play, both in terms of puzzles and time limitations, were used in order to enhance the game prior to its deployment as an embedded Induction activity.

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The Use of Process Simulators as Supporting – *But Not* Designing – Tools in Chemical Engineering Courses

Beneroso, Daniel

Robinson, John

University of Nottingham

daniel.benerosovallejo@nottingham.ac.uk

KEY WORDS: Process Simulation; Process Engineering; Process Design; Process Control; Aspen HYSYS

SUMMARY

Process simulations are made of mathematical models represented by a model architecture based on a feedstock flowing through interconnected unit operations and underpinned by a setup configuration chosen by the operator (i.e., units for magnitudes, components and thermodynamic packages). Consequently, process simulations are unavoidably full of assumptions, often case-specific, and contain defaults for many options when the operator have no preference that may interfere with the simulation output. This fundamental rationale behind process simulation should be consistently conveyed to engineering students, who may often wrongly assume that they can use such a software for designing safe, cost-effective and robust processes without necessarily understanding the limitations and assumptions made in the models. In this article, we consider the importance of discouraging the use of process simulators for process design. Instead, we propose an approach to the usage of process simulation software as a *supporting* tool in process engineering courses able to reflect real-world engineering practice. Process simulation is carefully introduced to students as a tool to help them to understand how different unit operations interact when joined as part of a larger, integrated process, and how such a process responds to fluctuating processing conditions, but recognising the inherent limitations of the simulation outputs.

INTRODUCTION

Engineering practitioners often consider process design as an art, whose practice is originated on contextual, holistic, and integrated visions of the world (Figueiredo, 2008). Mathematics and applied science are commonly used in this regard but as supporting tools to rank and select from the available alternative solutions to a well-defined engineering problem. Process simulators implement such a mathematical science by representing a pre-defined architecture based on material and heat streams flowing through interconnected unit operations, piping, pumps and compressors. However, the use of simulators have been reported not to help with the creative and imaginative part of process design or with the *know-how* generated from past real-case industrial experiences (Moran, 2015a).

LITERATURE REVIEW

Belton was the first author to propose a learning framework model for process simulation pedagogy in which students are to progress through consecutive levels of skill development, but no evidence on how the simulator may have enhanced students' conceptual understanding of the process working principles is reported (Belton, 2016). On the contrary, process simulations were described to be perceived by students as a source for questioning themselves about such underlying principles. Although the use of simulations to illustrate first chemical engineering principles could be a trigger for the student's cognitive predisposition to learning, promoting the usage of process simulations for accomplishing professional, complex tasks such as designing a process could make new graduates to be overconfident in simulation techniques, and eventually lead to a replacement of their own professional judgment. Not warning students about the limitations of simulation software inevitably leads to a poorer understanding and judgement of the process as a whole. This was already suggested by Silverstein, who discussed an approach to "learning through failure" for training students on the use of process simulators (Silverstein, 2004).

CONTEXT: THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

Process simulators are computer programs that can quantitatively evaluate model equations representing an operating process or facility, usually based on first principles. Despite the fact that simulators involve the usage of mathematical models not generally based on reliable real-world plant data to predict the response to a process, its use for the year three capstone engineering design project continues to be a normal practice in academia (Moran, 2015a). As stated by Moran, professional process design is virtually never based on the mathematical first principles used by simulators, and therefore the usage of such programs have a highly specific and limited range of application in the professional design process (Moran, 2015b). In our view, this practice may have a negative, dangerous impact not only upon critical design elements such as plant safety, economics and process robustness as also recognised by (IChemE, 1999), but also upon the engineering judgement abilities of the students. Nevertheless, an intuitive clutch of the ways in which a complex system fits and interacts together, and responds to changing operating conditions is where we believe process simulation has a major role to play in the chemical engineering curriculum. In this article, we report an approach – completely separated from process design teaching – to the usage of process simulators as *supporting* tools in the BEng/MEng Hons Chemical Engineering programmes at the University of Nottingham.

DESCRIPTION OF INTERVENTION / PRACTICE

Process simulation has been integrated within the Nottingham Chemical Engineering curriculum to *support* further engineering decision-making, and to avoid being considered as the main tool for designing processes. Students have to undertake two compulsory modules; namely, Process Engineering Project (PEP) in year 2 and Process Simulation (PS) in year 3. PS deals with steady state process simulation using Aspen HYSYS software, and students utilise their developed core technical knowledge to implement and run models including basic flowsheeting operations, gas-liquid contactors, heat exchange units and flow assurance. In PEP, however, students utilise their process control and operations knowledge to plan and operate a non-steady state process in order to produce a series of products to a given specification using the Fractionation Train Simulation 4310 from the TSC SIMULATION software. These two modules, namely PEP and

EVALUATION OF INTERVENTION / PRACTICE

By consciously driving students away from design practice, process simulation was introduced as a tool to *support* deeper student understanding of how processing units interact and react to fluctuating inputs within a larger process. Whilst tracking and evaluating how this proposed paradigm changes students' perceptions and attitudes towards simulation tools is challenging to quantify, some reflective commentary based on student feedback and performance over the years can be made.

DISCUSSION

The use of process simulators has undoubtedly had a positive effect upon the students' performance in their design projects, but not by assisting students in the process design itself. Instead, simulators have made them aware of the inherent challenges of design and have helped with its intuitive part. For instance, the PEP virtual environment gives students a unique perspective of non-steady state, the interconnectivity and interdependence of process units in series and the practical application (and limitations) of process control. Over the years, we have observed that the insights and learning gained by students in PEP has led to marked improvements in their year 3 capstone design project. The focus on start-up in the PEP simulator means that students are more confident in designing processes that can produce the desired output with variable input conditions. Consequently the design brief in year 3 explicitly specifies variable feedstock flows/compositions and variable product demand, safe in the knowledge that students have a firm grasp of the challenges to the designer. P&IDs are produced more accurately and more realistically given students practical experience with process control, particularly the use of independent feedback loops and indirect measured parameters such as temperature and pressure. Thirdly, and perhaps most important of all the use of a virtual environment in both PS and PEP imprints on students the importance of the holistic process to produce the target product, and discourages overly-detailed attention to and optimisation of individual unit operations. Prior to the introduction of the PEP start-up simulation students undertaking the year 3 design project would tend to default almost exclusively to the detailed design of a single unit, often at the expense of understanding how that unit needed to function as part of an integrated system. With students more focussed on the system rather than

individual units, they have gained a much broader appreciation of the overall design process and consequently perform much more effectively within their design teams.

CONCLUSION

Models in process simulators are full of assumptions, often case-specific, and contain defaults for many parameters that may interfere with the simulation output. Nevertheless, they can be effectively used to *support* student learning around how high-level holistic processes work. If only used in that sense, process simulators can help in improving students' abilities and intuition to design and operate integrated processes later in the course (e.g., in year three capstone design project) by following real-practice, established engineering methodologies in this occasion, rather than process simulators.

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Theme 4: Teaching Transferable Skills in Engineering

Introduction

Today's engineering students are expected to be knowledgeable of their subject *and* be capable of succeeding in academic and professional life. This means that students require the specific skills of their degree as well as 'transferable' skills that can be used across disciplines, sites of practice, and stages of life. Transferable skills enable students to confidently adapt their cognitive and communicative abilities to new situations and problems in order to continue making valuable contributions to work, study, and life. In order to excel at university and in a career, students must develop and hone transferable skills, including academic writing, critical thinking, research and teamwork. Educators play an important role in identifying these transferable skills and implementing the pedagogical exercises that make this skills development possible.

How transferable skills are taught varies due to considerations of timetabling, resources, and scope of student engagement. Hence, there are various approaches to transferable skill development, ranging from courses to workshops to in-class activities that occur at a specific moment or over the academic year. Whilst there are contextually unique approaches to the teaching of transferable skills, it is evident that these skills are important for students to learn at all levels of study. To consciously convince students of the importance in developing these skills, educators must communicate how transferable skills align to subject learning and career development. Clarifying the relation between transferable skills and subject learning is also relevant to persuading colleagues and fellow teachers on the necessity for embedding such skills development. Since transferable skills enable students to confidently cross modules with the ability to communicate and critique, which is significant for assessment and evaluation. By supporting student's development of transferable skills, educators are helping students to achieve at university and beyond. This is possible because the transference of skills from one domain to another allow students to adapt to unfamiliar problems, such as tackling a new assessment, and thrive in unknown or uncomfortable environments, such as a new job. Therefore, the teaching of transferable skills is a necessity in engineering so as to enable students to succeed both academically and professionally.

Dr Lauren Schrock, Teaching Fellow, EIG. University of Warwick.

An Academic Skills (ASK) Collaboration: Integration of Academic Writing in Engineering.

Bond, Richard

Brunel University London

Richard.bond@brunel.ac.uk

KEY WORDS: Academic Writing, Common First Year Engineering, Integrating, Collaboration, Curriculum Design

ABSTRACT

This paper shares reflections on integrating Academic Skills into a newly designed common first year engineering (FYE) module at Brunel University London (BUL). Combining research-led multi-disciplinary curriculum planning, active learning pedagogy and integration of study skills to a discipline-specific module, the pilot module aims to prepare students for success at university, in employment and to facilitate students' entry to the community of practice of engineers. Issues to be addressed include resolving the apparent conflict between large cohort sizes for a common first year and smaller classes for an active learning approach. Initial informal feedback has been encouraging, suggesting that research-led pedagogy, in collaboration with combined experience of teaching in Higher Education can be successful. Highlighting the link to expectations in industry appeared to motivate students to participate in class discussions and activities, however the limitations of ideal teaching spaces made it difficult to fully exploit the learning opportunities for all students. Further planning is required to find solutions to the apparent conflict between large class sizes inherent in the common FYE courses and active teaching pedagogy. Links with other institutions and with Digital Learning experts may provide a solution to this problem, while increased investment in infrastructure would also be beneficial.

INTRODUCTION

In Higher Education common FYE courses are increasing and universities have a greater focus of ensuring courses are relevant to industries. These developments come at a time when there is more attention paid to research-led pedagogy and the importance of providing support for students at all levels in Academic Writing and Study Skills. BUL aims to respond to these challenges by the development of a common first year in engineering that incorporates the messages from employers in engineering related industries while also integrating Academic Writing and Study Skills sessions into a module within the common first year.

The problems that arise from apparent conflicting goals, such as the increase in cohort size opposed to the practicalities of delivering active learning sessions with small groups in small classes leads to a potential clash. The implementation of the curriculum can potentially highlight areas of concern and on reflection of the issues, lead to solutions.

LITERATURE REVIEW / RATIONALE

Previous literature suggests common (FYE) is beneficial because it introduces engineering students to other engineering disciplines necessary for working in multi-disciplinary teams, although students may not be motivated when studying the non-core aspects which means that the relevance must be highlighted (Nedic *et al.*, 2010; Male and Bennet, 2015). In ongoing research, Mohamaddi-Aragh and Kajfez (2015) identified that discipline-specific FYE courses could differ from common FYE courses in building communities of practice and identity, which challenges the assumption that common FYE courses are better. This requires a creative response when designing a curriculum.

An active learning approach that is student centered with groupwork was successful in previous evaluations with FYE students (Muñoz *et al.*, 2015). Project-based Learning in FYE received positive feedback from students (Palmer and Hall, 2011) although Nikolic, Ros, and Hastie (2018) suggest flipped classroom approaches could be de-motivating for some first-year students.

AIM AND OBJECTIVES

The aim of this initiative is to provide Brunel University London (BUL) students with skills for transition to university study and employment. A further aim is to contribute to learning and teaching development in the BUL Engineering departments.

THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

The common FYE course was established in 2019 with 374 students in response to the increase in similar courses and to develop students' understanding of other engineering disciplines. Stakeholders were identified to form the Curriculum Design Group for a pilot module called Engineering Practice for divisions within the College of Engineering, Design, and Physical Sciences (CEDPS) at BUL. The group included academics from Civil, Chemical, Electrical, Mechanical and Aerospace, the Academic Liaison Librarians, Professional Development Centre staff and the CEDPS ASK Academic Skills Advisor. Other stakeholders were consulted, including BUL Engineering students. The group drew upon the industry experience and connections of the group members.

The Academic Skills included in the module were: groupwork, critical thinking, reflective writing, exam preparation, presentations, academic writing and report writing. The Curriculum Design Group agreed that these were the main topics to focus on, considering the experience of the group members with engineering industry experience, and from previous co-taught sessions and drawing from Brunel's careers consultant's networking with relevant industries. For example, the session on groupwork incorporated activities on personal skills identification and provided a framework for discussing critical thinking and reflective writing. The groupwork session incorporated extracts from recent engineering job vacancy extracts that highlighted the importance of groupwork skills. In small groups students were asked to solve a problem which guided them towards analyzing the skills that individuals bring to groups and how working together can solve problems. This led to two other activities, discussing strategies for working together on group projects and, through individual reflection, identifying the skills that each

student might bring to a group. Students are expected to develop a personal develop plan with their personal tutor which will be followed up on later in the module.

The sessions were planned to support students in each stage of their group engineering projects and academic staff covered other engineering practice skills including: technical drawing, artefact test planning, ethics, project management and sustainability. This is planned to be delivered in a mix of traditional and non-traditional teaching approaches, for example, sustainability is designed to be centered around covering the People, Planet, Profit, principles and the 2015 UN 17 Sustainable Development Goals with questions set in a Task-Based Learning approach throughout the presentation.

The Academic Writing and Study Skills sessions are delivered by the Academic Skills Advisor in collaboration with CEDPS academics and 2 Graduate Teaching Assistants (GTAs) per session. This increases the student to teacher ratio per session to between 1:15 to 1:20 depending on student numbers per workshop. Therefore, students are supported in academic content aspect and academic writing. The sessions include groupwork activities, pair/share tasks, individual work and short lectures. Teaching staff can engage with groups or individuals to provide guidance and support during the activities,

KEY FINDINGS

Engineering Practice is a new module and emerging findings can improve future sessions. The collaborative approach instigated by CEDPS resulted in clear communication throughout the process. This has been successful in part because the members of the Curriculum Planning Group have co-delivered sessions with the ASK Academic Skills Advisor or have attended BUL teaching and learning seminars. Therefore, through these established working relationships there is a commitment to the active approach for this module's delivery.

The students participated in the activities and, based on unsolicited comments made by individuals to the session facilitators, found them useful and enjoyable. There was a noticeable lack of students being distracted by mobile phones, or going off topic, as monitored by the facilitators during the sessions. A few students approached the Academic Skills Advisor both

before and after sessions, and in passing on campus to raise questions, seek advice and to provide further informal 'reporting back' from activities. The degree to which this indicates engagement is difficult to measure, but it can be taken to indicate that some of the students have found the activities engaging and further formal feedback will be useful.

The large student numbers were to some degree overcome by having a good student to teacher ratio with trained GTAs, relevant engineering academics and an experienced facilitator. The tiered lecture rooms proved to be an obstacle to reaching all students and to creating the desired degree of interaction both with and between students. In the one session where a flat room was available, the workshop proceeded as planned with no difficulties despite the large cohort.

DISCUSSION

Students can provide feedback through the Student Experience Committees (SECs) which are held throughout the year and module evaluations are emailed to all students. There is some evidence to suggest that university students experience feedback-fatigue therefore over-surveying is avoided (Mayhew, 2019; Wiley, 2019). Informal feedback has been positive. Some students have explicitly mentioned that they appreciate the interactive approach and GTAs report informal requests that other modules be conducted similarly. Students' attendance, participation and engagement in activities are good.

There are however numerous concerns over using student feedback as the only indicator of a module's efficacy. Issues such as attrition, employability and success in employment are difficult to measure and attribute, requiring methodological considerations and a longitudinal study.

Ideally, facilitators are able to engage with students to provide guidance and support in small cohorts. Murdoch and Guy (2002) reported that around 40 students constitute a small class. Furthermore, group activities are difficult in tiered rooms, therefore flat rooms are better for active learning. With a large cohort, coordinating rooms and times for smaller classes was difficult and therefore most sessions were delivered to larger cohorts of around 70 in tiered

lecture rooms. When flat rooms were available the student teacher ratio resulted in some successful workshops. Otherwise it was difficult to talk to students in the middle seats.

Groupwork activities depend on having good facilitators (Kavanagh, Clark-Murphy and Wood, 2011). The GTAs received recent training in academic practice and guidelines outlining the underpinning pedagogy which resulted in active listening and guiding students in activities. The academics involved have a range of experiences, training and teaching approaches ranging from interactive student-led teaching to traditional university teaching. The diversity of academics' teaching approaches is part of a broader debate affecting HE and as Graham (2015) points out, for busy academics teaching recognition may not be a universally shared priority. Attempts to address the issue can result in emotive discussion as reflected by comments on a recent article in the press (see The Guardian, 2018).

There are a number of engineering teaching practice issues that are emerging from the Engineering Practice module. Some of the members of the Curriculum Design Group already had established excellent working relationships which contributed to an understanding of the skills and knowledge that individuals brought to the team. Additionally, the module leader chaired the curriculum development meetings and ensured that meetings were scheduled well advance, detailed minutes were kept recording the development of the module, and highlighting action points, whilst ensuring that meetings were kept focussed and productive. Sub-groups were formed to deal with specialised topics as required and key individuals brought in as required to provide advice, for example, on the type of robotics kits that should be purchased.

CONCLUSIONS & RECOMMENDATIONS

The module is led by research and experience with key objectives to support students at university and prepare them for success in employment. As a work in progress, limited informal findings suggest that this has been a successful approach, although issues with adapting an active learning approach with a large cohort in tiered teaching spaces suggest that further solutions need exploration. This can be achieved through discussions with colleagues at conferences, emerging research and networking across the University with academics and support staff such as Digital Learning Advisors.

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Academic Language and Literacy for Mechanical Engineering: Interdepartmental Collaboration in Design and Delivery of Pilot Provision

Hendrie, Paul Lazar, Irina

Department of Mechanical Engineering, University of Bristol.

paul.hendrie@bristol.ac.uk

KEY WORDS: Mechanical Engineering, Academic Language, Literacy, Report Writing, First Year Undergraduates

SUMMARY

With increasing internationalisation in UK higher education, first year Mechanical Engineering undergraduates embark on their degree programmes with an increasingly broad range of expectations of lab report writing. To address this need, a discipline specific pilot programme consisting of three academic literacy workshops was developed at the University of Bristol in collaboration between staff at the Department of Mechanical Engineering and the Centre for Academic Language and Development. The workshops focused on techniques for writing lab reports, oral communication skills and succeeding in exams. They were offered to all first-year mechanical engineering students on a voluntary signup basis. Only 7 students signed up for the workshops in academic year 18/19, but student feedback indicated that they found them useful for developing their understanding of the department's expectations. The pilot provision also provided the basis for future collaboration and the potential for development of additional workshops. This paper concentrates on the workshop dedicated to lab report writing.

INTRODUCTION

The University of Bristol's academic language and literacy provision has been running at postgraduate level for a number of years. This provision involves the design and delivery of small group sessions in collaboration with academics from individual disciplines, with the purpose of equipping students to read and write more effectively within those specific disciplines. It is not targeted specifically at international students, but rather open to every student within the respective cohorts, on the basis that every student can improve their skill at reading and writing within their discipline, as nobody is born speaking academic English (Bourdieu et al., 1994). Recently a move has begun to develop such provision at undergraduate level at the university of Bristol. This paper outlines the design and delivery of one such pilot provision for first year mechanical engineering undergraduates.

LITERATURE REVIEW

Taking a discipline specific focus for literacy workshops draws on Lave & Wenger's (1991) idea of 'academic communities of practice', which suggests that students learn best by working together in 'disciplinary tribes' rather than being divided by language level or country of origin.

Bringing students together in such groups allows for a focus on the expectations of the specific writing tasks students are concerned with, increasing the relevance of the sessions to their needs. This can facilitate successful navigation of divergences in genre and features of academic writing across disciplines (Lea & Street, 1998) helping to address any uncertainty about expectations. Departments may provide guidance to students on writing lab reports, but additional opportunities to clarify and discuss expectations of written work are valuable for facilitating the transition of students to a new discipline. When developing such additional opportunities, it is important to ensure that they align closely with existing departmental guidelines to avoid confusion amongst students and duplication of effort amongst staff.

The workshops described in this paper aimed to be 'contextualised, embedded and mapped' (Sloan & Porter 2010). 'Contextualisation' was achieved through the use of relevant texts for students to analyse, such as extracts of student assignments and tutor feedback. Sessions aimed

to be 'embedded' through the integration of the sessions as closely as possible within their degree. Finally, sessions aimed to be 'mapped' by including them in the students timetables at a point of maximum relevance.

The teaching methodology drew on McWilliam's (2009) 'Meddler in the Middle' approach, whereby the tutor's role is to promote a critical and generative learning environment by 'interfering' strategically and purposefully in students' interactions. For these sessions, this involved drawing on students' own contributions as a classroom resource and encouraging active and purposeful analysis of writing samples.

The structure of the sessions followed a 'message, moves, mechanics' organisational pattern (Gillway, 2014). Through analysis of samples and marking criteria, students deepened their understanding of the expectations and academic conventions of their lecturers (ie the 'message' from the Mechanical Engineering department). These expectations were explored in greater depth to identify how they might be addressed (the 'moves'). Finally, students identified particular strategies and tools with which they might accomplish these moves effectively (the 'mechanics').

CONTEXT: THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

Undergraduate students undergo, in most cases, a sharp transition when starting their university degrees (Harvey et al, 2006, Briggs et al, 2012). Putting aside the challenges associated with living away from home, family and friends, considerable uncertainty relates to the expectations associated with an undergraduate degree. Such uncertainties can arise from new teaching and learning styles, new environments, expectations of independent study, and more. In this context, it is understandable that additional support is needed, particularly when students come from a diverse range of cultural and educational backgrounds.

At the same time, in a working environment where communication and wider enterprise skills are key to most careers, it is important for educators to support students in developing them throughout their degrees (Andrews and Higson, 2008). In recent years, there has been a shift

towards embedding these into the taught curriculum and show students how these skills, that may wrongfully seem disconnected from their chosen degree speciality, are in fact highly relevant. This is especially true in the case of technical degrees, where many students start their studies thinking that success is only related to the technical and scientific knowledge they will acquire throughout their studies (Direito et al, 2012).

There are approximately 600 students enrolled across the 4 years of our undergraduate Mechanical Engineering programmes, with a 60%: 40% home to international student ratio. These students have experienced different educational systems before commencing their degree, and even though they all performed well in those contexts, their language and literacy abilities vary. Many students are not native English speakers, and even with a successful outcome in the requisite language tests, the language barrier persists in some cases.

To support international students, the university implemented an English Diagnostic Test to offer better insight into the students' language skills. For those who failed this test, a language unit that students could take alongside their other units was introduced. Given that this unit was optional and only offered to those failing the Diagnostic Test, the Department team decided to revise its provision. Student and staff feedback also suggested that a more inclusive approach was appropriate, where all students, regardless of their background, should have the opportunity to improve and consolidate their academic language skills.

Taking all the above factors into account, the Department plan is to design embedded components that are delivered to all students and then roll this out to other departments, ensuring consistency across the undergraduate engineering programmes. With this in mind, we decided to design the pilot workshops presented in this paper and ensure that students' feedback was taken into account at every step in the process, informing the future embedded provision.

DESCRIPTION OF INTERVENTION / PRACTICE

Staff at the Department of Mechanical Engineering, and Centre for Academic Language and Development at the University of Bristol collaborated to develop and pilot a short series of

academic workshops to equip first year students of Mechanical Engineering to write lab reports more effectively and achieve greater success in their exams. The collaboration began in December 2018, when representatives of the two departments met to discuss the academic literacy needs of the mechanical engineering students, perform a needs analysis and develop a draft scheme of work for the 3 pilot sessions. The target cohort for this intervention was all first-year Mechanical Engineering undergraduate students.

For the pilot provision, we designed 3 x 2-hour sessions, to take place in weeks 17, 19 and 20 of the academic year. These sessions focused on lab report writing, communicating as an engineer, and techniques for succeeding in exams, as outlined in the table below. The voluntary signup basis allowed students to choose which session(s) they wanted to attend and sign up for them individually.

Week:	Focus	Learning outcomes
17	Writing reports effectively	<ul style="list-style-type: none"> • Use sources appropriately in written work • Connect your ideas effectively • Write with clarity and directness • Write concisely and precisely
19	Communicating as an engineer	<ul style="list-style-type: none"> • Communicate effectively within a group • Write reflectively • Relate your learning to professional contexts
20	Succeeding in your exams	<ul style="list-style-type: none"> • Read textbooks for a purpose • Take notes effectively • Revise effectively for your exams • Focus your response to a task

Figure 1: The scheme of work for the pilot workshops

The workshops were classroom-based and planned for groups of up to 16 students. The sessions were 2 hours long and timetabled in a slot which was determined appropriate by the timetabling department. Students were emailed and invited to attend.

Following the development of the scheme of work, the sessions were designed using an academic literacies approach. For the lab report session, this is exemplified through the

development of analytic activities of feedback and student work from previous years, and reference to the expectations of the markers as identified in the marking criteria. Such an approach enables the development of activities for students of all levels of writing or language proficiency to deepen their understanding of how to meet markers' expectations more effectively.

The content of the first session was informed by:

- The marking criteria for lab reports
- The previous year's lab report submissions
- Feedback comments on these submissions
- Sample examination questions

Feedback comments from samples of these reports were captured and analysed to identify common themes and points for inclusion in the workshop materials. An example is given below:

1 Connect your ideas: Report structure

1.1 Look at the comments below, which are feedback from markers of last year's lab report. Which sections of the report do these comments refer to?

- 1) You need to use more references and explain your motivation more, and yes this is a university task but pretend that the aims are to really balance a rig - and be more specific.
- 2) This is only one possible error source - you need to discuss more possible error sources and discuss them more in detail. Also, at the end, you're expected to provide a suggestion to improve this lab, future work and application of it to real world.
- 3) Hardest section to write. Think of it as summarising the entire report, begin with the aim, motivation, brief experiment description, results and what they mean.
- 4) Very good - you have found good sources to back up your points, and to check that they are as expected. Your consideration of the errors was also a good start for this level. In future, you should also consider the limitations of the experiment in terms of the points you are making, and suggest how it could be improved.

Figure 2: Sample of an exercise relating to feedback analysis.

As the experiments described in the previous year's samples were the same ones, a decision was made not to use extracts of the reports for analysis, but rather to focus on the functional language within those extracts. This avoided 'giving away' the content of the experiments while still allowing the students to analyse and learn from the rhetorical 'moves' that student writers made in last year's reports.

An example activity using this approach is given below:

2.5 In pairs, analyse how the writer has written this section. How is the text linked? Where may they have included the features of a discussion section (which you identified in exercise 1.3?)

From Table 1&2, a sign represents _____. Theoretical forces are calculated by _____. Because _____ is assumed to be _____, _____ is not necessary to be considered.

Differences between _____ and _____ are used to avoid _____. _____ experienced the largest magnitude of _____, so the force applied was _____. This value corresponds with the theoretical value of _____ [1]

The graph of _____ shows _____. Hence, _____. It also shows _____. The mean percentage error from both sets of results is _____, which is _____. The sources of error might be _____ because _____, and _____, so _____. Additionally, _____.

For improvement to reduce errors, _____. Moreover, _____. Furthermore, _____. Finally, _____.

In real situations, _____, and _____. The instrumental and human errors are _____.

Figure 3: An exercise focussing on the use of functional language in a discussion section of a lab report.

A further activity involved the analysis and discussion of language in lab reports to assess clarity, conciseness and precision. This aimed to develop students' ability to edit their own work and extract useful principles for their own writing. An example of this activity is given below:

4 Write clearly & directly

As well as expectations of the content of your reports and use of sources, your department has expectations of your word choice.

4.1 Consider the following extracts. Where might the writer's word choice be improved?

In addition to this, the nature of the apparatus made it very hard to accurately set the angle of the mass, and the radius of it so one assumes that that is the primary source of error.

Nowadays, pin jointed truss is often used in infrastructures.

The percentage errors of all members are smaller than 7%, which is acceptable.

Failure due to imbalanced rotors has devastating consequences as seen in a few online videos.

In this experiment, we will try to balance a rotor by adding mass _____

EVALUATION OF INTERVENTION / PRACTICE

The intervention was evaluated with a short feedback form which was completed anonymously by each student after each session. This form gave the intended learning outcomes of each session and provided space for students to add comments about what they found effective from the sessions and what could be improved. The comments from the students on the lab report session are listed below:

Comments from students: what was useful?
<ul style="list-style-type: none">• <i>Small size, seminar-like feel</i>• <i>Read feedback on lab reports</i>• <i>English language guidance</i>• <i>Looking at report structure and what should be included in each section</i>• <i>Looking at precise and concise sentences</i>• <i>We learned how to structure our lab reports sentences with cohesion and concision</i>• <i>Looked through each section of the report</i>• <i>Looking at what should be found in a lab report</i>• <i>How to build an analysis paragraph</i>• <i>How to structure a lab report correctly</i>
Comments from students: what could be improved?
<ul style="list-style-type: none">• <i>Maybe have a few examples of good lab reports</i>• <i>Could be run earlier in the year (only 2 labs left)</i>• <i>Just do the workshop earlier in the year since from now on only 1 report is left.</i>

Figure 5: Student feedback on the lab report workshop

DISCUSSION

The feedback indicates that students found several aspects useful, and their comments highlight the value they found from analysing the structure of lab reports and discussing the expectations for each section. The overall feedback seems positive, and constitutes a promising foundation for the ongoing collaboration in increasing students' understanding of lab report writing, developing useful teaching material, and deepening professional connections between staff across the collaborating departments.

Students indicated 2 main areas for improvement: the first - 'provide a few examples of good lab reports' may be inadvisable due to the similarity of the experiments from year to year. The second related to the lateness of the timing in the year. This lateness was due to the sessions being piloted in the second half of 18/19, and for the 19/20 provision, a decision was made to run the sessions much earlier in the year to achieve more appropriate mapping.

The numbers of students who signed up was much lower than expected, at only 7 students. Some of the reasons for this may include:

- The need to schedule the sessions at 9am due to heavy timetabling constraints.
- Low perceived need for/interest in the sessions.
- Conflicting student priorities (ie workload in the weeks the sessions were held)

To address the potential impact of these factors, the following points were discussed:

- Future sessions could be timetabled later in the day to encourage attendance
- Sessions could be embedded in the timetable rather than offered on a signup basis
- Students could be visited in induction week to inform them of the provision
- The scheme of work could be reviewed and additional material developed to refine the focus on student needs.

CONCLUSIONS & RECOMMENDATIONS

Based on the outcomes of the sessions, it was decided to build on the progress made in 19/20 by timetabling the sessions for earlier in the year, advertising them more regularly to students via email, and developing embedded provision for 20/21. These actions are all underway this academic year.

In addition, the session evaluation forms have been revised in 19/20 to feature a Likert scale numerical rating system for each learning outcome. This aims to generate quantitative feedback on student perception of the effectiveness of the teaching towards each learning outcome in the session.

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More than Maths: Transition into-through-work: Work-Based Learning Higher Education Engineering Programmes

Smith, Christopher J. M.

Institute for University to Business Education, Glasgow Caledonian University,

Christopher.Smith@gcu.ac.uk

KEY WORDS: Transition, Work-Based Learning, Affective Domain, Degree Apprenticeships.

ABSTRACT

Degree Apprenticeships (DAs) - through-work Work-Based Learning (WBL) Programmes (Gray, 2001) – offer a new mode to provide industry-relevant programmes. Applicants for DAs are not just recent school leavers, but offer the potential for experienced engineering practitioners to gain both improved knowledge and competency aligned to their workplace. For those returning to education (and entering Higher Education for the first time), due consideration is required about how to support transition into (and through) their programme. However, this transition for such students (mature, part-time) is an under-researched area of practice. This poster will outline important considerations in transition into through-work WBL programmes, following on from previous research (Smith and Wilson, 2017). Affective attributes are identified as being equally as important to knowledge aspects and encourages the use of all aspects of level descriptors (SQA, 2012; QAA, 2014) – knowledge, practice, skills and behaviours - to be used to frame transition practice and support.

INTRODUCTION

The emergence of Graduate Apprenticeship standards in England from 2015 and in Scotland from 2017 have brought a new industry-academia dynamic around educational programmes that are relevant to industry. Interestingly, these programmes see a high proportion (51% in 2016/17) of mature students studying in a part-time mode (OFS, n.d.). Whilst much work has been done around transition – for example, QAA Scotland Enhancement Theme on Student transitions (QAA, n.d.) and work by Higher Education Academy (see for example, O'Donnell, Kean and Stevens, 2016) - research into transition of mature students into through-work engineering work-based learning (WBL) programmes is sporadic. Therefore, the focus of this paper is to evaluate factors influencing transition of mature students into such engineering WBL programmes; this research builds on previous empirical work of a bridging module designed to transition experienced engineering practitioners into an undergraduate part-time engineering programme (Smith and Wilson, 2017).

The paper will first summarise the findings from the previous empirical study, before conceptualising these findings in terms of existing UK qualifications frameworks and level characteristics. Subsequently, a review of literature around Recognition of Prior (informal) Learning and Engineering Mathematics (including Mathematics Anxiety) will be used to extract considerations for practical transition of mature, experienced students into a through-work Engineering WBL programme.

LITERATURE REVIEW

The previous empirical research (Smith and Wilson, 2017) examined how a bridging module supported transition into an undergraduate, part-time engineering programme for applicants with sub-degree level qualifications. Whilst it identified important course design factors – scaffolding mathematics and science and the use of an integrated project to provide a practical focus to synthesise new and experiential knowledge – it also highlighted the development of wider transferable and cognitive skills (academic and digital literacies) and emphasised the importance of students' behavioural attributes; in particular, resilience, flexibility, motivation and tenacity were identified as being a significant contributor to student's success in the bridging

module and then when they progressed onto the undergraduate programme. These factors reflect the five characteristics of the Scottish Curriculum and Qualifications Framework (SCQF), namely “Knowledge and Understanding”, “Practice: Applied Knowledge, Skills and Understanding”, “Generic Cognitive Skills”, “Communication, ICT and numeracy skills” and “Autonomy, accountability and working with others” (SQA, 2012); SCQF framework is similar to other UK-based frameworks so it is used here as has explicit and consistent characteristics across all levels, thereby ensuring that the emergent model is adaptable.

Admission criteria are one method to articulate the required expectations to gain entry but primarily focus on prior certified learning. Reflecting individual and contextual circumstances, as well as experiential and informal learning, for entry is possible through Recognition of Prior (informal) Learning (RPL/RPiL); RPiL is also referred to as Accreditation of Prior Experiential Learning (APEL). RPiL claims involve a dialogue between the applicant and the university, and so support transition and familiarisation around the programme, its expectations and knowledge gaps. However, RPiL in engineering is often underused and may reflect varying personal values and beliefs and institutional politics when judging equivalency of understanding (Davison, 1997 cited in Hagar, 1998) – which typically underrate informal learning. Hagar (1998) indicates that “staff involved will have varied views on the purpose of RPL”, so having suitable staff involved in the RPL process is vital to permit an equitable and inclusive consideration; Whittaker, Brown, Benske and Hawthorne (2011) support that specialised staff are required. Additionally, these authors outline that more tailored approaches are required to gather evidence for RPiL (rather than just a portfolio) and advocate for structured individual interviewing and use of level descriptors (such as SCQF) to enable programme level mapping. In summary, skilled and empathetic staff are required to facilitate this process and understand the individual strengths and areas of development of each applicant (insights that support individualised transition).

Whilst RPiL may allow for recognition of experiential knowledge, it needs to be recognised that engineering is a scaffolded discipline with a requirement to possess certain core knowledge, including mathematics, at key stages (including on transition into a programme). Gallimore and Stewart (2012) helpfully recognise that simply providing a diagnostic test before the start of studies to assess this knowledge has several drawbacks, including whether a test without preparation is reliable. For learners returning to education, testing knowledge of mathematics may cause anxiety (Dowker, Sarkar and Looi, 2016). Moreover, attitudes to Mathematics -

“mathematics self-concept” (Dowker, Sarkar and Looi (2016) - can interplay with Mathematics Anxiety, namely negative self-perception around mathematics ability will cause anxiety. Additionally, Dowker, Sarkar and Looi (2016) indicate that tertiary students show mathematics anxiety, more so with apprentices than university students, and that this impacts on performance in mathematics. Saritas and Akedmir (2009) summarise factors influencing Mathematics Anxiety as relating to i) demographic factors, ii) instructional factors and iii) individual factors. Consequently, considering engaging instructional methods that develop confidence and the self-directed nature of learning are important, as well as recognition of the importance of mathematics as part of an engineer’s identity (but as Craig (2013) reports this is an under-researched area).

Additionally, it is noted in Harris et al (2015) that there is a view that Mathematics should be the core of an Engineering curriculum, but this is an approach that fails to connect to interests of students and the application to engineering problem solving. Furthermore, Harris et al (2015) notes also that general mathematics does not help students to bridge the gap of applying mathematical concepts to unknown problems. Programme approaches where Mathematics is “well integrated in the engineering curriculum facilitating contextual relevance of mathematical abstracts to engineering concepts” is required (Henderson and Broadbridge, 2007, cited in Abdulwahed, Jaworski and Cameron, 2012). Such a highly contextual approach is mirrored in the approach of Klingbeil et al (2004) and through their longitudinal study (Klingbeil and Bourner, 2015). In addition, the benefits of a controlled investigation using Mathematica to develop a conceptual approach to mathematics (rather than a procedural approach) are recognised as beneficial (Roddick, 2001 cited in Abdulwahed, Jaworski and Cameron, 2012).

So, in the context of mature students, tailored approaches that develop self-efficacy and self-perception around Engineering Mathematics are required, as is demonstrating the importance of Engineering Mathematics to solve problems and an essential aspect of a Degree Engineer’s identity.

CONCLUSIONS & RECOMMENDATIONS

The above literature review highlights that including the behavioural aspects in designing any transition programme and support for mature students entering WBL engineering programmes are highly relevant. Using all aspects of the level characteristics within qualifications frameworks (such as the SCQF) provides a framework structure in designing transition programmes. Further comparative empirical studies are required to review approaches taken by different Higher Education Institutions to determine which transition designs are most effective. It is hoped that, through the poster discussions, interested researchers will engage with these discussions to allow this follow-up research to take place.

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Debate as a Tool in Engineering and Sustainability Education

Alaswad, Abed Prince, Mark

Aston University

a.alaswad@aston.ac.uk

KEY WORDS: Debate, Engineering Education, Sustainability Education, Active Learning.

SUMMARY

Debate is an active education tool which is widely used to teach undergraduate students in social science and humanities courses, but less common in Engineering and computing courses. Debate, in this context, refers to the establishment of contradictory positions on a topic or question and inviting students to form 'teams' or parties each tasked with the responsibility of promoting those positions to an audience through mediated oral discourse.

A well-integrated debate can help students to improve their understanding of the subject, improve their critical thinking, increase the retention of the information gained, enhance communication and team work skills, promote their confidence and helping them to better construct their ideas and thoughts in logical and sound structure. It is well known that integrating this approach in an active learning environment will promote a student's engagement and motivation to learn.

In this paper, the practice of integrating the debate on the climate change response pathways (Adaptation, Mitigation and Geoengineering) in a final year course taken by Mechanical Engineering students will be presented. The effect of using this practice on students' engagement, module feedback and marks will be highlighted.

INTRODUCTION:

Compared with traditional didactic teaching, it is accepted that active learning strategies produce increased content knowledge, greater enthusiasm for learning, development of critical creative thinking skills, and an improve in students' engagement with the topic taught. Several active learning strategies are popular in engineering disciplines such as real-world problem solving, group projects, student presentations and peer response polling systems. The use of debate as a mode of active learning mode was found to be far less popular in engineering courses when compared with other disciplines such as humanities and social sciences.

Debate is regarded as an educational tool to systemise discussion between students on specific topic or question, where teams with contradictory positions on that topic will attempt to make the audience accept their position. A well-planned and integrated debate can help students to increase their understanding of the subject, improve their confidence, communication and team-working skills, enhance their reflection and critical thinking practice, and learn how to construct their ideas and thoughts in a sound and logical structure. Furthermore, it will lead to increased student retention of the information learned, as it is interest-based learning that engages the mind thoroughly.

In this paper, debate as an education tool will be described, mentioning its benefits and drawbacks when applied to different subject areas. A brief literature review will be used to investigate its impact on different educational metrics such as attendance, engagement, knowledge depth, retention of knowledge and soft skills. Furthermore, integrating this educational tool in the teaching of a module in the Mechanical Engineering programme at Aston University will be outlined, highlighting the effect of such intervention on students' experience and marks.

LITERATURE REVIEW

As an education tool, it was claimed that one of the most important benefits of debate is that it promoting working together in teams and having a positive and constructive interaction when performing a collective task (Zare and Othman, 2013). Students who learn using cooperative approaches such as debate showed greater academic ambition and improvement, longer retention of the knowledge gained, higher level of critical thinking, higher self-esteem and more constructive communication. Furthermore, when compared with other individual study activities, the collaborative approach results in higher-level reasoning, more creative solutions and greater transfer of knowledge within the team itself and the wider classroom environment. Aiming to measure the students' perception about educational debates, it has been found (Goodwin, 2003) that while few students reported distress and anxiety about the competitive nature of debates, the majority expressed positive feelings claiming that the debate encouraged them to explore the content of the course deeply and that it promoted independent learning for themselves.

In engineering courses, it was noted that non-mathematical courses such as material science can be mainly theoretical, leaving the educator with fewer options to encourage active learning. In (Hamouda and Tarlochan, 2015), the authors incorporated team debating as an education tool in the Materials Science module, in which students claimed that the applied method was very enjoyable, encouraging them to attend and to engage highly in the course, and enabled to let them reflect on higher level of Blooms Taxonomy. Moreover, it is stated that the students improved their time management and team working skills and student grades and attainment increased significantly. In a study conducted by (Alford, Surdu, Tarhini and Vandercoy, 2002), it was claimed that using debate as a teaching tool in engineering course, such as Artificial Intelligence was highly supported by students. Authors recommended to choose a controversial topic within the subject to let students share and evaluate different viewpoints. To support their arguments, it was noticed that students needed to do independent research and to improve their verbal communication skills.

It has been mentioned by (Snider & Schnurer, 2002) that applying debate approach in education was found to push students to adopt a greater responsibility for comprehension of the subject and to invest more serious study effort. In learning controversial subjects, debating was found

a great tool to allow students to appreciate the complexity and the multi-faced nature of subjects. This education tool can provide students the opportunity to synthesize course information, encourage related independent research, improve critical thinking, and develop verbal communication skills. Debate sessions were introduced to 2nd year medical students by (Mumtaz and Latif, 2017), where over 180 students participated in opening argument, rebuttal, formal debate, and in closing remarks from each side. It enjoyed an overwhelmingly positive reception with 78% of the students agreeing that it improved their critical thinking, 80% agreed that it helped them understand the importance of listening to different views, and 75% agreed that it helped them to realise different strategies to convince others. The public nature of the debate is motivating the students naturally to perform well (Aclan, Noor and Valdez, 2016). Moreover, the effect of this approach on soft and transferrable skills is greatly appreciated by students with communication and team-working skills seeming to receive the greatest benefit from this approach.

THE ENGINEERING EDUCATION INTERVENTION

The intervention took place in the Engineering Design and the Environment module, which is delivered for the third year BEng/ MEng Mechanical Engineering at Aston University. The module aims to outline how engineering designs impact on the environment and to give an in-depth account of impacts in climate change and ocean acidification. Life cycle assessment is introduced as a method of categorising and quantifying impacts. In particular, students learn about the three main pathways of responding to the climate change issue, namely adaptation, mitigation and geoengineering. By implementing the debate as an education tool, the team was aiming to increase the students' engagement, reflection and retention of knowledge associated with sustainability and responding to climate change.

Following a brief scientific background on how climate change is happening, and the effect of greenhouse gases on the climate, the three pathways responding to the global issue are introduced (Figure 1). At that point, students are given the chance to express their views on which approach is more effective, and indeed to choose their group project under that pathway.

Responses to climate change




▶ Mitigate	▶ Adapt	▶ Geoengineer
		
<ul style="list-style-type: none"> ▶ Keep nature as it was ▶ Minimise the impacts ▶ E.g. renewable energy, energy efficiency, careful resource management... 	<ul style="list-style-type: none"> ▶ Change is inevitable ▶ Adapt and survive ▶ E.g. water technologies, food security, flood defences... 	<ul style="list-style-type: none"> ▶ Take control of climate change ▶ Carbon dioxide removal ▶ Solar radiation management

Figure 1: Responses to climate change (debate teams)

While lectures support learning of different technologies under each pathway, the debate between students in different pathways serve as the backbone of the module. During the lectures time, students were given different opportunities to practice debating and to show different aspects of their choice based on their independent research. At the end of the module, a public session was made where each group presented on their project and how their approach to climate change is more efficient than others. A space for question and answers followed each presentation where other students tried to contradict the presented view. A following conclusion lecture was used to show the advantages of each approach, and how all different approaches are needed urgently, and side by side, to deal with this global and major matter.

Instead of teaching different pathways used to respond to climate change using traditional lectures and tutorials, the new approach has used the educational debate as the backbone of the module which encouraged students' attendance and engagement throughout the module sessions. It has been noted that there was about 32.5 % increase in student attendance at lectures and group projects sessions compared with the last version of the module, making this particular module one of the most attended ones in the final year. Feedback gained from students via an online survey at the end of the course also improved on the data from the previous year, with special improvement of over 20% on the students 'encouragement and participation in the classroom. An improvement in the students' retention and level of the knowledge can be noticed by the higher average marks and pass rate achieved. Other verbal

and written feedback showed that a majority of students was found to be highly motivated to research beyond the lecture notes, to understand the multi-faced nature of problems, and to appreciate the collaboration value inside the team, and in between other teams. The public debate session which was held by the end of the group projects was also seen by students as a great way to practice public communication with unspecialised audience.

DISCUSSION

From the results achieved, it is clear that implementing the debate as an education tool helped to improve the students' motivation, engagement, depth and retention of knowledge gained, and soft skills. Although using such approach is not typical for Engineering Education, the subject itself where students have the room for different views, along with briefing recent research projects under each pathway, helped the students to facilitate their choices and debating based on rich and accessible literature in the field. Future work is planned to use similar approach in other modules taught in the same programme.

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Step up to Master's Study: Redesigning Professional, Study & Research Skills for Student Success

Masood, Maryam; Schrock, Lauren; Andrews, Jane; Knowles,
Graeme, Clark, Robin,

Engineering Innovation Group, WMG, University of Warwick.

jane.andrews@warwick.ac.uk

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SUMMARY

This paper focuses on the teaching of professional, study and research skills to a large cohort of Master's Students within WMG, a large Engineering Department located at the University of Warwick. Taught as an 'optional extra' the Study Skills & Research Methods Module (AKA, ReMe) is not accredited and in previous years has been taught on an 'opt-in' basis using a series of two to three hour long voluntary workshops. A review of colleagues' perceptions of learning and teaching within WMG found general dissatisfaction with students' professional, study and research skills; with many colleagues indicating that they believed that in its previous format ReMe could be improved to better equip students with the required levels of professional, study and research skills and competencies needed to succeed on their individual courses. A review of the ReMe module followed, resulting in a complete redesign.

It is this issue that this short paper examines, briefly critiques some of the literature before explaining what changes have been made. The conclusion argues that it is important to get the building blocks of professional, study and research skills in place to assure student success both at university but also in their later careers.

INTRODUCTION & BACKGROUND

Through the articulation and publication of international declarations and agreements, including the Paris Declaration (2018) the Kyoto Declaration (2015), the World Federation of Engineering Organisations draws attention to the vital role played by engineers in building and sustaining contemporary society (WFEO, 2019). Despite such treaties, reports of predicted future shortages of suitably qualified engineers may be found across the media, with much debate focusing on the question of whether further and higher education is adequately resourced or equipped to produce sufficient numbers of suitably qualified engineers to meet future demand (for further discussion see Carnavale et al, 2011; Salzmann 2013; Rothwell, 2013; Lawlor, 2016; Engineering UK, 2019; McCulloch, 2019). Yet whilst the issue of potential future shortages of engineering talent is important, it is not the most pressing issue. Indeed, wider discussions about higher level engineering education extend to whether the engineering curriculum is suitably aligned to the needs of current and future employers. Questions regarding *what* engineering students are taught focus on both technical and engineering skills and knowledge (Walther et, al., 2011; Malcom & Feder, 2016), as well as softer transferable study and professional skills (Hoffman et al, 2005; Charyton & Merrill, 2009; Zhou, 2012).

It is this question of transferable study and professional skills that the module discussed in this paper focuses. Set within a large Engineering Department in a Russell Group University a review was undertaken of how Research Methods and Study Skills (ReMe) are taught. The result of this review has been a complete revamping of the ReMe module with an intentional redesign built upon the principles of the RVS Model of Engineering & Applied Science Education (Clark & Andrews, 2014).

Focusing on the practical and academic challenges associated with teaching study and professional skills to a large cohort of ostensibly Chinese students, this paper represents a work-in-progress that is being continually reviewed, evaluated and redesigned. The challenges of redesigning a module for over 1,200 students enrolled on a range of different engineering and management MSc programmes are discussed and an overview of the new approach briefly examined.

SYNOPSIS OF LITERATURE

There exists a depth and breadth of literature focusing on pedagogic practice and employability. With the context of reviewing and renewing the ReMe programme, the concept of pedagogic frailty (Kinchin, 2009, Kinchin et al, 2016) was identified as being particularly relevant. Occurring when a combination of academic, institutional and external pressures result in teaching staff consistently using teaching methods they are comfortable with, pedagogical frailty manifests itself within a classroom culture in which innovation and change are viewed with suspicion (Canning, 2007; Kinchin et al, 2016). The result is a normalisation of a teacher-centred pedagogy (Bailey, 2014), that in promoting the transmission of facts and theories (Kinchin, 2009), results in low levels of student engagement (Kinchin et al, 2016) and does not promote deep learning (Marton & Saljo, 1976).

THE REME MODULE REVIEW

The review of the ReMe module occurred over an eight week period and mostly examined the taught content of the module. Undertaken by a pedagogical researcher with 12 years' experience of teaching Research Methods and other social-business focused modules to graduate level engineering students, the review followed a mixed methodological approach including a critical content analysis of teaching material, teaching observations and unstructured interviews with students.

During the review four major challenges were identified:

1. A lack of student engagement with study skills sessions (which in turn impacted performance across the programmes)
2. Low levels of student engagement with research methods sessions (which had consequences for the dissertation)
3. An overloading of content on the VLE.
4. A poor use of constructive alignment (Biggs, 1996) across the module in terms of limited congruence with the wider programmes and a lack of cascading and relational learning outcomes at the module and individual level.

DISCUSSION: WHAT IS A WMG GRADUATE?

Prior to determining what professional and study skills are needed for engineering students and future managers to succeed, a working definition of what a WMG graduate should embody in terms of an ability to holistically apply a wide range of skills, knowledge and competencies was developed. Aimed at establishing a baseline that encapsulated the wider learning outcomes from the various programmes across the curriculum, the task of defining WMG 'Graduateness' adopted a functionalist epistemology incorporated within a psycho-cognitive pedagogic approach. Additionally, in order to make sure that this definition was appropriate for the 21st Century Engineering Classroom, research conducted by two of the paper authors into engineering education and student expectations and experience was taken into account (Andrews & Clark, 2017, 2018a, 2018b; Clark & Andrews, 2014, 2017), and further contextualised by professional body perspectives regarding the role of engineering within society (Engineering Council, 2019; RAEng; 2015, 2017).

The result of this synthesis is the following 'working definition' of a WMG graduate:

WMG graduate engineers and managers need to be able to draw upon a set of key individual, professional and critical thinking skills to identify, investigate and solve a wide range of technical, socially constructed, managerial and environmental problems, and in doing so be able to effectively communicate and explain both challenges and solutions to a non-expert audience.

Having provisionally articulated the key WMG MSc graduate attributes, the next stage of the process was to redesign the module itself and in doing so articulate a set of learning outcomes that aligned with the various postgraduate programmes whilst also representing a coherent and logical pedagogic strategy.

REDESIGNING ReMe FOR STUDENT SUCCESS

In what turned out to be a fine balancing act, the need to encourage independent learning and innovative teaching resulted in the gradual development of a signature pedagogy (Shulman, 2005; Lucas & Hanson, 2016) in which a blended learning approach incorporated a purposefully constructed pedagogy.

Taking account of the graduate attributes discussed earlier in the paper a set of learning outcomes were developed to frame the module. A substantial review and renewal of the teaching content followed in which a number of changes in how ReMe is taught were enacted:

1. **The use of RVS** (Clark & Andrews, 2014): The new curriculum is constructively aligned (Biggs, 1996) to the wider academic programmes and purposefully designed so as to reflect the students' learning journey. Divided into three distinct teaching phases ReMe now comprises:
 - **Introductory Phase:** Taking account of the large body of work regarding the need to engender belonging in students as soon as possible within the academic year (Thomas, 2002; Clark et al, 2013; Clark & Andrews, 2014), this phase is aligned with welcome week and provides students with key knowledge and information needed to familiarise themselves with their new learning environment and settle into WMG.
 - **Step up to Master's Study:** Scheduled in the first 8 weeks of term 1, a series of professional and study skills workshops provide students with a wide-range of professional and study skills.
 - **Research Methods for a Successful Dissertation:** Beginning as term 1 draws to an end, research methods teaching starts off with a broad overview of the scientific approach to research. In term 2 a series of workshops focusing on managerial, engineering and social research methods and practices will equip students on a broad range of courses with the skills they need to undertake a graduate level research project.
2. **Increased Opportunity to Engage with ReMe:** To make sure that as many students as possible get the opportunity to participate in ReMe, fortnightly Saturday large group

workshops are held. Students attend three-hour long workshops either in the morning or afternoon. These workshops provide a detailed introduction to a particular topic, adopting flipped, active and traditional approaches to promote engagement.

- To capture those students unable to attend on a Saturday, a series of ‘refresher’ sessions are held over a two week period. Students who have a genuine reason for not attending the Saturday session are given priority on the booking system (amongst others, this includes students who have caring responsibilities or who need to work at weekends)
- Following on from the Saturday workshops, a series of in-depth ‘follow-up’ workshops are held over a three week period. These are taught in small groups of around 30 students and provide the opportunity to explore each topic in detail. The workshops have to be pre-booked and continue until all students asking to attend are given a place

3. **Redevelopment of Learning Materials:** The learning materials are being re-written so as to better reflect the wider requirements of the MSc programmes.

- All powerpoint presentations are pre-recorded and uploaded onto the VLE. These recordings provide a summary of the key knowledge and theories students need to know and are accompanied with a transcript which allows those students whose first language is not English, or who have a disability or learning difficulty to more easily access the material. In this way the ReMe team are working hard to promote inclusivity within all aspects of our teaching
- A series of workbooks are being developed to support the workshops and to provide students with independent learning tools that they can explore at their own pace. These are directly aligned with the workshop content and are released to coincide with the weekly teaching.

4. **Redesign of the VLE:** The VLE has been ‘wiped clean’ and redeveloped anew. In addition to providing access to all of the blended learning materials clear links to internal and external resources are provided.

5. **Improved Student Communication:** Weekly updates and emails are sent to the students to remind them of what is occurring in the following week and also to send useful hints and tips about learning.

6. **Enhanced Student Support:** Weekly 'drop-in' sessions are held in the MSc common room to enable students to meet on a one to one basis with lecturers. This resource in itself has enhanced the level and type of pastoral support available to students.

Still very much early on in the process, it is not possible to comment on the success of the redesign. Despite many colleagues expressing concern about the previous approach, the changes were not met without opposition. Some colleagues who'd expressed concern about ReMe also disliked the idea of it being redesigned with the resistance to change proving frustrating at times. Practical problems with finding sufficient classroom space and fitting ReMe into the timetable at one point seemed insurmountable and were only overcome by the introduction of Saturday teaching.

The redevelopment of the learning and teaching materials is ongoing and will continue throughout the year before being reviewed and revised for the next academic year. At the moment the new approach is very much a pilot, with sufficient flexibility so as to be able to change direction if necessary. In the first four Saturday sessions student engagement has been high. With the module content currently focusing on professional and study skills, the more complicated and theoretical side of ReMe will be taught in the Spring of 2020. It is then that the value of the blended learning materials will come into play.

CONCLUSION: MOVING FORWARD

In conclusion, the redesign of ReMe has moved teaching and learning in WMG into unknown territory. Large group teaching of 500-600 students at a time was previously unheard of and although Saturday teaching had been trialled previously it had not been successful. Hence the new approach is not without risk. Furthermore, redesigning a module to suit the wide learning styles and professional needs of over 1,200 students has not been easy. However, in doing so there can be little argument that it is important to get the building blocks of professional, study

and research skills in place to assure student success both at university but also in their later careers.

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A Reflective Case Study: Teaching Statistics to Third Year Engineering students at Brunel University London

Parnis, Noel

Brunel University London

noel.parnis@brunel.ac.uk

KEY WORDS: Probability, Statistics, Engineering

SUMMARY

Teaching Probability and Statistics to engineers has its own blend of challenges and benefits. This paper describes and shares some reflections on an intervention, created by the Academic Skills (ASK) team at Brunel University, to support teaching of Statistics in a third year engineering module. Key challenges observed include varying statistical background amongst the cohort, time allocation, and students struggling with the concepts of unpredictability. However, it is possible to take advantage of engineering students' above-average mathematical ability, their affinity with data, and their tendency to visualise concepts. A practical component where students work in the lab to analyse and discuss a given data set has helped the students engage with the content. Underpinning all this is a strong and effective relationship between the adviser and the relevant lecturer.

INTRODUCTION

Probability and Statistics play an important role in engineering practice and research. In industry, two key areas are reliability engineering and quality control. Experimental design involves a fair amount of statistical analysis, and looking for relationships between sets of data is at the heart of research. With the increased use of simulations to predict and understand

the behaviour of complex systems, a clear understanding of Probability and Statistics is essential for engineers.

Students tend to find the concepts of randomness and uncertainty difficult to understand (Wilson, 2002), leading to a general disliking of the subject. Staff who are not specialised in Statistics tend to be reluctant to lecture the subject, leading to a higher risk of insufficient statistical content in an engineering course. Professional services, such as Academic Skills (ASK) at Brunel University, thus have a key role to play in providing the necessary support to academic staff and students for the teaching and learning of Statistics in engineering.

The ASK team is a central service supporting all students by helping them develop the skills they need to become independent learners and thrive academically. The team focusses on three main areas: academic writing, Mathematics and Statistics. Support for Statistics is provided via themed central workshops, departmental sessions and individual sessions during open office hours or by appointment.

This paper describes the involvement of ASK in a third year engineering module at Brunel University, specifically teaching Probability and Statistics via lectures and labs. It also discusses reflections made on the teaching, as well as on individual student appointments. Currently, this support is in its second year of running.

LITERATURE REVIEW

Several papers address the difficulty of teaching Statistics to engineering students. For example, Wilson (2002) describes some of these challenges, suggesting some approaches to mitigate the issue. Similarly Petocz & Reid (2005) report problems such as students finding the theory boring and difficult to understand, lack of motivation and a perception that Statistics is not relevant to engineering. In addition, studies such as Ictenbas & Eryilmaz (2011) suggest that engineering students tend to learn by solving problems, running experiments in labs and 'building stuff' - i.e. kinaesthetically (and often in combination with other learning styles).

Suggestions to address this issue are varied and wide-ranging: Wilson (2002) explains a number of practical 'tried and proven techniques' (p.3), such as sequencing of topics, appropriate use of notes and worksheets. Neumann et al. (2012) suggest that working with real-life data helps students with their motivation and levels of engagement with Statistics courses. Additionally, Shahjahan et al. (2018) give an account of their experience using educational technologies, such as statistical software, to teach Statistics, and present the results of a student evaluation of their approach, insisting on the importance of practical work in the lab.

CONTEXT

ASK Statistics advisers have observed that many students have a general disliking of Statistics, and especially Probability, most likely because few understand the concepts of randomness and unpredictability. Particularly in engineering, students are used to a deterministic world which can be predicted according to the laws of Nature. This therefore presents a significant challenge when trying to teach Statistics to engineering students.

DESCRIPTION OF INTERVENTION

The aim of this intervention was to provide students with sufficient knowledge of statistical methods, as they prepare to go to industry or continue in research. The support provided consisted of five two-hour weekly lectures, followed by a lab session. All material was examinable at the end of year exams. The first half of the lectures aimed at consolidating the basic theoretical background, followed by introducing probability distributions, sampling theory and hypothesis testing.

The second half focussed on understanding and learning how to interpret results from statistical tests using a statistical software package – IBM SPSS. The material covered when to apply each test, the main underlying assumptions, how to interpret the results, and, importantly how to draw meaningful conclusions. The emphasis was on the application of statistical hypothesis testing, aiming to teach students how to read, interpret, accept and explain the messages in their data.

As in the case of other similar interventions (Wilson (2002)), the design and delivery of this intervention had to address some key challenges, mainly:

- Students' different levels of statistical knowledge at the start of the course
- The limited time allowed for Statistics in the module
- Delivering at a pace such that all material is covered whilst allowing students time to understand
- Adapting to engineering students' strengths (learning style)

There were several students in this group with basic Statistics knowledge. In discussion with the relevant lecturer, ASK decided to start from the basics, at the risk that this could be boring for some students. From feedback received, a number of students appreciated this section, as they had not done Statistics for some years. The section was kept short and was covered at a fast pace.

With limited time, and with the varied statistical background of the students, a major challenge has been to cover a wide range of topics in a few weeks. In conjunction with ASK, the responsible academic re-adjusted the balance between Statistics and other topics in the module, managing to add an extra lecture for Statistics. A decision was taken not to compromise the extent of the content, and instead a careful review led to trimming of detail in certain sections.

With the limited time and vast range of topics to be covered, there was the temptation to rush through the material. Students have had little time to reflect and ask questions, with the risk that they could end up reacting adversely to the subject. Feedback after every lecture indicated areas where the pace was too fast, allowing the adviser to revisit these areas in the subsequent lecture.

Students who choose to study engineering often find it difficult to learn simply by listening and reading (Ictenbas & Eryilmaz, 2011). This cohort were no exception, and we observed that students were more engaged during examples in class, in the labs and with working with practice sheets. However, keeping them engaged was a challenge when covering the basics of Statistics, which requires a certain amount of background learning, before undertaking practical work in the lab.

Lecture material was delivered using animated PPT slides. The material included some MS Excel models, built by the author, and also publicly available models, to demonstrate certain concepts. Students were encouraged to build their own models and experiment with them in practice worksheets. Additionally frequent short breaks were incorporated, and simple short Maths puzzles were used to help students re-focus.

During the first half of the lectures, several problem-based examples drawn from real-life engineering situations were used. Before the solution was explained by the adviser, students were allowed a few minutes to work in pairs on a possible solution approach. To encourage students to engage better in class, solutions to these class problems were not given in the notes handouts. To consolidate understanding, students were given weekly practice sheets, with solutions posted on-line a week later. Practice sheets included a range of problem questions of varying levels of difficulty, addressing the topic covered during the lecture, and typically included one or two 'challenge' questions to get students to reflect deeper and explore further the topic. A small prize was offered to the first three students to hand in the correct solution to one particular challenging question. To consolidate further the understanding from the first half of the course a seminar (tutorial) session was held to discuss some of the questions from the worksheets.

In the second half of the lecture series, the statistical tests were presented individually through animated PPT material, using data sets with engineering relevance wherever possible. In the lectures, focus was not on how to run the tests, but rather to show typical outputs, explaining how the results are interpreted, and conclusions drawn.

An essential component of the course was the practical two-hour workshop in the laboratory. In this session, students were first introduced to SPSS, and were given around thirty minutes to go through on-line introductory material about SPSS prepared by ASK. Students were then given a simple data set, and an associated worksheet which first asks students to perform simple tasks in SPSS, and then takes them through the basic statistical tests. For each test, the worksheet explores the students' understanding of the assumptions and the results. One test at a time, using animated PPT material, the adviser explained how to run the test in SPSS, allowed the students to attempt the associated questions, presented and explained solutions, and then allowed time for students to discuss the technical interpretation of the results.

For additional support, students were offered the possibility to see the ASK adviser during Statistics open office hours, or to set up one-to-one appointments to discuss any issues or misunderstandings. Finally, a revision session closer to the exam period was held.

Open student feedback was collected after every session, allowing the adviser to make amendments inbetween lectures. Additionally, private conversations with students (at office hours) indicated that they were satisfied with the level of difficulty and pace of delivery.

DISCUSSION

From addressing the above key challenges, we realised we could leverage on the engineering students' strengths when teaching them Statistics. The initial stages of the course involved a fair amount of Mathematics skills which the students were comfortable with, through other modules of their course. This was presented to the students as an opportunity to put into practice and to good use some of the Maths skills they had been working on previously. Similarly, previous experience indicates that engineering students are typically comfortable with learning new software packages in a short period of time, and this in fact was of great help when it came to introducing them to a statistical package that was new to them.

Furthermore, engineering students tend to visualise situations and problems (Ictenbas & Eryilmaz, 2011) - an important skill to have in Statistics, particularly when looking for patterns in data or reading graphs. This proved to be a powerful tool to the adviser, as many times it was possible to draw tables or graphs to explain data structures or relationships between data elements, or to explain certain concepts.

Running this intervention with engineering students was also rewarding to the instructor. The first was the realisation from discussions during office hours that some students were understanding the subject and, importantly, appreciating its relevance to their career. Informal feedback suggests that student engagement increased for the lab session. This is supported by the perceptibly higher level of discussion and participation of the students during this session, as well as by the relatively higher attendance (nearly double the average lecture attendance) for the lab session.

These sessions increased students' awareness and attendance of ASK office hours, and have helped form a stronger relationship with the Engineering department while increasing further requests for Statistics support from the department.”

CONCLUSIONS & RECOMMENDATIONS

The following conclusions are suggested for consideration when planning any intervention similar to the one described:

- It is important to find out the background statistical knowledge of the students, establishing a common denominator as a starting point. Although not attempted so far in this intervention, an initial assessment test could be administered early in the year, and the course content adjusted accordingly.
- Flexibility is required when developing learning outcomes, module and course content, ordering of topics, and detail to be covered. This of course is not always possible –but the more flexibility allowed the better.
- A strong and effective partnership with the relevant academic staff is paramount to create bespoke sessions with examples from engineering.
- Collecting feedback, in a simple and efficient manner, after every lecture, and being able to take corrective action as the course runs, is an effective way of improving quality.
- The experience over the past two years shows that students tend to engage better when examples and case studies relevant to the field are used.
- The use of software models and on-line tools helps students visualise Statistical concepts in the classroom.
- Such Statistics courses should have a significant element of practical work in the laboratory where students learn how to run and interpret results from some statistical tests.
- At the end of the second year of running, a questionnaire will be used to collect structured feedback, to draw some more conclusions and ideas for improvement.
- Practical statistical work involves a fair amount of interpretation of results and the reporting of results in an easy to understand and clear format. Engineering students

typically struggle with this, and central professional services such as ASK could potentially help with this.

With interventions like this, it is hoped that students leave University better equipped with the necessary statistical and analytical skills required for industry and research.

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UK Engineering Education Research Network: 2019: Invited Panel: What can we learn from other disciplines?

Introduction

The WMG & School of Engineering 2019 EERN Organising Committee are pleased to introduce this inaugural panel to our academic community of Engineering Education Researchers. This introductory paper, written by the Panel Chair, David Pontin, of WMG, University of Warwick, provides a short overview of the five papers to be presented as part of the Panel.

In today's multidisciplinary and cross-cultural world, the need for engineers to be able to work with and lead teams of colleagues from a range of different disciplines, and who possess a wide variety of technical skills and competencies, has never been so important. In preparing young people to work in a global setting, where the notion of a single lifelong career in one organisation is a thing of the past, it is imperative that contemporary engineering education is able to learn from and work with colleagues in other disciplines. It is this ideology of multidisciplinary pedagogy that underpins this panel.

Tasked with preparing future engineers to take up professional roles that don't yet exist, so that they are able to solve social, environmental and economic problems that have yet to be imagined, engineering educators have a duty to adopt, adapt and append best practice from other disciplines into our teaching. This inaugural panel aims to provoke discussion and debate about how we can best do this. It showcases excellent pedagogic practice used in the teaching of graduate level management students. Eight colleagues from three universities have collaborated in putting this work together. An interesting, thought provoking and interactive discussion is promised.

Dr Jane Andrews, Editor, EERN, 2019.

Innovation in Learning & Teaching Project Management, Risk and Strategic Marketing

Pontin, David. Dacre, Nicholas. Senyo, PK. Reynolds, David. Adigun, Lydia. Wakenshaw, Susan. Harvey, David. Olson, Nancy.

david.pontin@warwick.ac.uk.

KEY WORDS: Project Management, Strategic Marketing, Interdisciplinary, Engineering Education, Internationalisation

List of papers

1. Is an Engineering Project Management Degree Worth it? Developing Agile Digital Skills for Future Practice.
Nicholas Dacre, PK Senyo, & David Reynolds
2. Interdisciplinary Research Methodologies in Engineering Education Research
David Reynolds & Nicolas Dacre
3. The value of business simulation games to enable students to acquire the key skills employers require.
David Pontin & Lydia Adigun
4. Value co-creation and University module design: A case study of marketing simulation based Strategic Marketing module design.
Susan Wakenshaw & David Harvey
5. Internationalisation: beyond professional competencies and learning outcomes in a changing landscape
Nancy Olson and David Reynolds

Dacre, Senyo and Reynolds in their paper “Is an Engineering Project Management Degree Worth it? Developing Agile Digital Skills for Future Practice” tackle head on one of the top issues of our time. The rapidly changing landscape as we transition from the industrial to digital age. In the workplace due to the complexities of modern projects along with the exploding quantities of data available Engineering managers are increasingly looking to the latest digital technologies to manage these challenges and gain competitive advantage. These include Artificial Intelligence (AI), Big Data, Augmented and Virtual Reality (AR/VR), 3D Printing and Digital Twins. The Agile approach born out of the new technologies therefore needs to be embedded within our teaching and learning alongside the traditional approaches. As the practice emerges there is an opportunity and need for increasing the relationship between business and academia and the argument for applied research in this area is made.

The subject of research is pursued in more depth in Reynolds and Dacres paper “Interdisciplinary Research Methodologies in Engineering Education Research”. Drawing on a comprehensive review of the Engineering Education Research (EER) literature this paper unpacks some recent debates and explores the themes of “rigour” and “appropriate evidence” in EER as well as some historical themes within the different disciplines. This is therefore useful as an introduction to various terminologies, frameworks, models as well as more recent thinking in EER. As well as providing some research methods underpinning this suit of papers this also helps to make previous research more accessible to practitioners and as such serves the ambition of bringing the business and academic communities closer together.

In the practice paper “The value of business simulation games to enable students to acquire the key skills employers require” Pontin and Adigun focus on 2 examples of project and risk management simulation exercises taught at post graduate level and consider the effectiveness of this learning and teaching approach. Particular emphasis and discussion concerns those skills that industry leaders claim they need for potential new managers and where the current gaps exists. The claim is made that simulation exercises can provide realistic scenarios, do enjoy excellent student engagement and can provide a safe environment where these skills can be developed. However there is more learning that can be drawn from the experience and future research could focus on how to capture this learning for future retrieval, reflection and then use in personal action development plans. There is also a need for greater empirical evidence to understand more fully this learning experience and drive its development.

Wakenshaw and Harvey in their case study paper “Value co-creation and University module design: A case study of marketing simulation based Strategic Marketing module design” provide an alternative discipline view and link the simulation into the module design. They respond to the criticism that traditional Business education is too theoretical and distant from the real world (Nisula and Pekkola 2019). The traditional methods of knowledge transfer have limited effectiveness. The concept of constructive alignment proposed by Biggs (2003) is used to propose a method of module design that links student-centred, learning outcome based teaching with the module content and the skill set developed through the marketing simulation.

In the fifth paper which completes our set Olson and Reynolds broaden and deepen the subject further looking at the internationalisation of project management and higher education and the complexities and challenges that this changing landscape present. Focussing on the skill set that organisations operating in this arena and looking for and drawing on the international project professional competency frameworks (APM, PMI, IPMA, GAPPS) the paper seeks to explore what learning environment is most effective in the acquisition of these competences. Conclusions are drawn from 3 research investigations covering a 10 - 15 year period and the theme of cultural intelligence is reflected on by educators seeking to ensure the skills that employers and students are searching for are transferred.

These 5 papers written by a multi-disciplinary team of academics and practitioners from 2 UK Universities together present a unique blend of insight, practice and recommendations for future research. The authors hope they will be useful to the engineering education community and as a catalyst for debate and a resource for the development of teaching and learning in these areas.

Is an Engineering Project Management Degree Worth it? Developing Agile Digital Skills for Future Practice

Nicholas Dacre ^a, PK Senyo ^b, & David Reynolds ^c

^aUniversity of Southampton, ^b University of Portsmouth, ^c University of Warwick

Nicholas.Dacre@southampton.ac.uk

KEY WORDS: Project Management, Agile Digital Skills, AI, Innovation, Project Manager

ABSTRACT

Engineering managers are progressively tasked with leveraging digital technologies and innovations which have yet to be fully developed, to seek out opportunities and challenges in complex project contexts. However, there is a disparity between knowledge gained from engineering development programmes, and the rapidly changing landscape of modern project practice, which requires professionals to effectively engage and deploy relevant agile digital skills in practice. For example, complex engineering projects increasingly employ dynamic digital technologies such as Artificial Intelligence (AI), Big Data, Augmented and Virtual Reality (AR / VR), 3D Printing, and Digital Twins, which require managers to quickly adapt to changing constraints through agile digital skills. Therefore, this paper seeks to focus on exploring the role of engineering project management programmes in developing knowledge and agile digital skills relevant for future project practice. Through an outline review of project management development programmes, this research paper suggests that their inherent value for engineering project managers, is largely dependent on a combination of applied research, engagement, and agile digital skills development for future practice.

INTRODUCTION

There has been considerable growth in engineering project management related development programmes which aim to equip future practitioners with the knowledge to address typical project-based challenges (Ojiako et al., 2011; Ramazani & Jergeas, 2015). For example, higher education institutions offer an array of project related master degrees and bachelor programmes (de Valence, Best, & Watt, 2007). These are generally embedded with subjects associated with project management practice, such as Business Management, Engineering, Operations, Strategy, Innovation, Construction, and IT, that reflect the discipline's interdisciplinary themes (Themistocleous & Wearne, 2000). As such, there are an estimated 700 project management related masters courses available for university students to attend internationally, and in excess of 200 available in the UK (StudyPortals, 2019). However, engaging a broad spectrum of current and future practitioners can be challenging (Goswami & Broadbent, 2017; Reynolds & Dacre, 2019).

Project related development programmes are underpinned by buoyant employment opportunities with an average of 60,000 related jobs in the UK, and over 300,000 in the US (ZipRecruiter, 2019). Project management also plays a vital role for economic and social development, responsible for the employment of around 2.13 million full-time equivalent workers, and contributes an estimated £156.5 billion of gross value added to the UK economy (APM, 2019). However, solely leveraging core technical skills is seldom sufficient in responding to rapidly changing digital landscapes (PMI, 2018). For example, currently in excess of 80% of all job vacancies require some form of digital skills (Nania et al., 2019), and 82% of project professional have identified digital skills as an important aspect for future practice (APM, 2019).

Although the demand for experienced project professionals with digital skills is resilient (APM, 2019; Kispeter, 2018; Nania et al., 2019; PMI, 2018), developing programmes which address future practice challenges remains challenging (Andrews & Clark, 2017). Furthermore, there is a disparity between future project management agile digital skill requirements in an increasingly changing technology-driven innovative project landscape, and engagement approaches adopted in development programmes (Filippaios & Benson, 2018; Ojiako et al., 2011; Ramazani & Jergeas, 2015). With a paucity of studies which specifically focus on the value of development programmes in response to future agile digital skill requirements, the main research focus of

this paper is: “What is the role of engineering project management programmes in developing knowledge and agile digital skills relevant for future project practice?”.

AGILE DIGITAL SKILLS

The context of digital engagement in the workplace is gaining momentum (Dacre, Constantinides, & Nandhakumar, 2015), further raising a pressing need for digital skills in professional contexts (Kane et al., 2015). For example, the UK government commissioned a number of studies to identify potential digital skills gaps in the workforce, and the importance of digital skills development for the economy (Kispeter, 2018; Nania et al., 2019). These studies identified different levels of digital abilities across the workforce, ranging from novice to expert, however findings suggested that the impetus for digital skills largely remains constant regardless of experience or expertise.

Agile Digital Skills can be interpreted as the mediation between practitioners and innovative technologies such as Augmented and Virtual Reality (AR / VR), 3D Printing, Digital Twins, Big Data, and Artificial Intelligence (AI), and the ability to exploit these in order to capitalise on opportunities, and overcome challenges (APM, 2019; Filippaios & Benson, 2018; Kispeter, 2018; Nania et al., 2019; PMI, 2018; Senyo, Liu, & Effah, 2019). For example AI, which specifically employs agile digital skills, is increasingly permeating into modern project related practice (Cakmakci, 2019; Dam et al., 2018; Nicholls, 2017).

The concept of AI was originally coined by John McCarthy back in 1956 (McCarthy et al., 2006) in an attempt to ascertain whether computers could reason like a human, since then there have been two notable periods of low development and limited research engagement referred to as AI Winters. Largely occurring between 1970s and 1980s, and secondly between 1990s and 2000s (Grudin, 2009). However, nascent disruptive technological innovations and engagement with Big Data means that project professionals are increasingly stepping out of the AI winter into the 4th Industrial Revolution (Dam et al., 2018; Nicholls, 2017; Waboso, 2018).

The 4th Industrial Revolution represents the convergence of technology and innovation through the increasing digital transformation of organisations, services, and products (Skilton &

Hovsepian, 2017). Thus, the technological-driven resurgence of AI takes us from Machine Learning to Machine Thinking, it provides an executive interface between project managers and Big Data and helps build better decision making bandwidth. However, although AI promises opportunities for project success, without project professionals' ability to expertly draw on agile digital skills in mediating this technology in project environments, risk of project failure remains a mitigating factor. Therefore, these disruptive technologies in project contexts require project management development programmes which address the increasingly agile set of digital skills and expert knowledge required in order to fully leverage potential opportunities and mitigate risks and challenges in future practice.

PROJECT DEVELOPMENT PROGRAMMES

Project based development programmes are inherently challenging and difficult to design, and implement to fully engage an interdisciplinary audience (Ojiako et al., 2011). In their meta-analysis of 8 years of engineering education studies, Andrews and Clark (2017) suggest five key areas in making programmes relevant for future engineering practitioners; (i) Accreditation, (ii) Active Learning, (iii) Core Technical Skills, (iv) Transferable Competencies, and understanding the (v) Engineering Context. Adopting (i) an accreditation process into programmes offers quality guidelines, (ii) active learning reflects a dynamic engagement context, (iii) core technical skills represents fundamental future problem solving approaches, (iv) transferable competencies encompass broader softer skills, and the (v) engineering context outlines the environment.

The concept of core skills is particularly relevant to agile digital skills development, however Andrews and Clark (2017) recognise the acute challenges in embedding these competencies for future practice with limited resources. Furthermore, the relationship between knowledge expertise of educators and the ensuing ability of their audience to engage with technologically challenging concepts, where the former lack confidence in more advanced aspects of a subject, can adversely affect the transfer of knowledge and emphasis of skills development (Jones, 2017). There is also evidence from extant studies that suggests that “an academic’s experience in industry also influences their judgements on the importance of professional skills” (Beagon & Bowe, 2018, p. 67). Finally, the changing nature of technology, its interpretation, use and implementation, inherently reflects its evolution in both theory and practice (Blacklock, 2018;

Budu, 2018; Malik, 2017), and despite this mandate for project related management development programmes, research suggests that historical approaches require appraisal anew (Ramazani & Jergeas, 2015; Winter et al., 2006).

DISCUSSION

The discipline of project management has been historically embedded in practice through the development and implementation of methodologies such as PRINCE2, links with the Association for Project Management, and the Project Management Institute. Given the historical nature of engineering project management as practice-driven, an opportunity for a research-driven approach is apt and refreshing. From the extant engineering related project management and agile digital skills literature, there are indications that a synergy between these two areas may lead to the development appropriate knowledge relevant for future projects. While there is great potential for using project management to develop knowledge and agile digital skills-based projects there are a number of issues that need attention.

First, there is a need for research informed engineering project management programmes. Given that project management is practice driven, there is a tendency of programmes to focus on anecdotal evidence from practical issues. However, to ensure that engineering project management programmes are relevant for future projects, there is a need for programme development to be driven by research informed evidence. With this, future practitioners will be exposed to current issues that are relevant to practice instead of relying on anecdotal evidence. In addition, using research informed evidence will enable better understanding and knowledge assimilation as real-world examples can be used in delivery of the programme.

Second, there is a need for deliberate inclusion of areas on emerging technologies such as AI, VR and Big Data and 3D Printing (Senyo et al., 2019) in engineering project management programmes. Largely, project management programmes are not designed with strong emphasis on gaining a holistic skill on the use of emerging technologies. Whereas project management programmes traditionally offer some agile digital skills, the noteworthy opportunity in recent times now calls for deliberate inclusion and focus on emerging technologies. With this, engineering project management programmes will then offer more agile digital skills in addition to project management knowledge that are relevant for future practice.

Lastly, there is a need for engineering project management programmes to be designed to allow seamless transition from theory and practice and vice-versa. Learning and acquiring theoretical knowledge about emerging technologies is a good starting point. However, there is a need for opportunity to put this knowledge to practice. More often, actors do not have the opportunity to practice theoretical knowledge acquired. However, research has shown that learning is more effective if theory and practice are linked (Andrews & Clark, 2017). Thus, for engineering project management project programmes to be effective in developing knowledge and agile digital skills, there is a need for a medium for the application of theoretical knowledge. For example, the use of business and project simulation games can help bridge theory and practice (Petri et al., 2019; Pontin & Adigun, 2019), and the concept of gamification which is the use of game elements in non-game contexts (Deterding et al., 2011) has been shown to have positive aspects on motivation and engagement (Dacre et al., 2015; Dacre, Gkogkidis, & Jenkins, 2018). Prior studies also suggest that the concept of developing programmes in partnership with stakeholders can support a synchronous relation with future professionals, helping to not only engage them, but also underpin the nature and structure of the programme in order to address their expectations (Dacre et al., 2018).

CONCLUSIONS

The discussion in this paper suggest that historical project management development approaches which employ limited use of innovative learning techniques, offer a narrow platform upon which practitioners may develop the necessary agile digital skills to respond to rapidly changing digital landscapes. Equally the relationship between theory and practice is acute in the field of project management, in that “in a fast, changeable and digital world, the cooperation between industry and academia is essential to prepare the students to a successful employment” (Cruz & Saunders-Smits, 2017, p. 66). It is therefore important for project management programmes to ensure students develop practice-based transferable and critical thinking skills to adapt to rapidly changing technological environments.

The review of agile digital skills, suggest that these play a vital role in seeking opportunities and overcoming challenges by proactively leveraging innovative technologies in rapidly changing

project contexts. For example, in this study we positioned the development of agile digital skills as one of innovation and control, in that this suggests an actor's ability to proactively influence innovative technologies and adapt to changing digital landscapes with agility. Thus, this study argues that in the context of engineering project management, practitioners should engage with agile digital skills development to leverage the benefits derived from innovative technologies for future practice. However, future practitioners are expected to develop knowledge and agile digital skills for practice which has yet to be developed. Thus, the matter of relevance for practice emerging from theoretical frameworks and knowledge expertise which may underpin the core essential project management capabilities, remains salient in preparing future project practitioners (Andrews & Clark, 2017; PMI, 2018).

In order to address the main research focus of this paper, practically there is a need for engineering project management programmes to address future business needs by offering applied research and agile digital skills. In addition, project management programmes should offer knowledge that is domain independent and can be applicable in diverse areas. Moreover, project management programmes should be solution oriented to address future practical business problems. Given that this study represents a foundation for future debates, the areas of engineering project management and emerging technologies offer several avenues for ensuing studies. First, future research may explore potential solutions emerging technologies can be used to develop engineering project management. In addition, further studies may investigate the impact of emerging technologies on engineering project management. Similarly, there is need to understand how organisations adopt and use emerging technologies in projects. Finally, future research may explore governance and regulatory issues on the use of emerging technologies in project management.

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Value Co-creation & Resource Integration

A Case Study of Strategic Marketing Module Design

Wakenshaw, Susan & Harvey, David

WMG, University of Warwick

Susan.wakenshaw@warwick.ac.uk .

KEY WORDS: Module Design, Simulation, Case Study, Value Co-Creation, Resource Integration, Strategic Marketing

ABSTRACT

Student-centred and learning outcome-based learning is becoming increasingly important in higher education. In addition, how to reduce the gap between the teaching and learning in the classroom and practices in real world is another issue to be addressed in higher education. Learning-outcome based module design has been discussed extensively as one approach to module design and to overcome these problems in the education literature. One of the key challenges of learning-based module design is constructive alignment in the process of module design and delivery. Our paper aims to address this challenge by applying the concept of co-creation in particular resource integration from a service ecosystem perspective. We proposed a method to enhance alignment between student learning outcomes, module content and the skills required by the marketing simulation.

INTRODUCTION

Student-centred and learning outcome-based teaching are becoming increasingly important in higher education. The key issue is to concentrate on constructive alignment in the process of module design and delivery. In the meantime, in order to reduce the gap between the teaching and learning in the class room and the real business practices, computer simulation has been adopted widely in business education. However, due to this practice, the constructive alignment becomes even more challenging for the module design and delivery. Our paper aims to address this challenge by applying the concept of co-creation in particular resource integration from a service ecosystem perspective. We proposed a method to enhance alignment between student learning outcomes, module content and the skills required by the marketing simulation.

LITERATURE REVIEW / RATIONALE

- Student-Centred, Learning Outcome-Based Teaching

Student-centred, learning outcome-based teaching is based on the idea of constructive alignment. When we design the module, we start from asking the question “what do we want students to be able to do or perform’. Performance determines learning, which in turn determines content. This is in contrast to a lecturer-centred module design process which starts with determining content, then learning, then performance. Proponents of constructive alignment argue that this approach promotes deeper, more independent learning, which can be applied to solving practical problems outside of the classroom (Biggs, 2003).

Business education, according to Nisula and Pekkola (2019) has been too theoretical and distant from real-world business practice. They argue that **this is often the case** in traditional classroom settings, where teachers ‘transfer knowledge’ and students passively receive knowledge. In response to this, various experiential learning environments such as computer simulations, can be used to improve learning, by enabling a collaborative process between students and teachers. Computer simulations attempt to reflect the basic dimensions of a business environment, with many variables and different types of data. Typically, student teams make a number of business decisions and compete against other teams in a given market

scenario, over several rounds. At the end of a round, each team receives results and feedback on their performance.

The learning benefits of computer simulations have been supported by various studies based on Bloom's taxonomy of learning domains; cognitive, affective and psychomotor. Anderson and Lawton (2009) and Clarke (2009) argued that computer simulations can improve learning on the cognitive and affective domains and can be particularly effective at improving the learning and engagement of poor and average students. Dadidovitch et al (2008) and Nisula and Pekkola (2019) researched psychomotor and skill-based learning and showed improvements in efficiency of task completion between the beginning and the end of the simulations. However, there are criticisms of using computer simulations in business education. Teach and Murff (2009) found that simulations can become too complex for students to understand and Lainema and Makkonen (2003) argued that the short time between each round of a game reduced the sense of reality for the participants.

Key challenges of implementing computer simulations in business education include:

- 1) how to assess and measure the performance of the students and
- 2) how to align learning outcomes and other module content with the knowledge and skills required by the simulation. Our paper aims to address the second challenge. In order to address this issue, we applied the concept of co-creation in particular resource integration from a service ecosystem perspective to enhance alignment between student learning outcomes and module content with the skills required by the simulation.

- Value co-creation from service ecosystem perspective

Value co-creation is a concept increasingly accepted in many domains including education (Diaz-Mendez, 2012; Schumann, Peters and Olsen, 2013). One dominant school of thought for value co-creation is service dominant logic (SD-logic). It is suggested that value is co-created through actors' service provision and exchange via resource integration. Service involves applying resources/competences/skills for the benefit of others or oneself. Service exchange entails interactions between people and organizations through applying skills and competence for the service of others (Vargo and Lusch, 2004; Lusch and Nambasin, 2015). There is clear distinction between operant and operand resources. Operand resources are typically physical, often

tangible and static (e.g. natural resources, raw materials or physical products) (Hunt and Derozier, 2004; Lusch and Nambasin, 2015). Operant resources are often intangible and dynamic (e.g., a human skill, both physical and mental)” (Lusch and Nambasin, 2015, p.160). Operant resources are typically human (e.g. the skills and knowledge of customers and employees), organisational (routines, cultures, competences), informational (technology) (Hunt and Derozier, 2004). Thus, Operant resources are resources that “act on other resources (operant or operand) to produce effects—that is, they act or operate on other things rather than being operated on” (Lusch and Nambasin, 2015, p.160). The latest discussion of value co-creation in the S-D logic community is from a service ecosystem perspective proposes that value is co-created through actors’ service provision and exchange via resource integration coordinated and constrained by actors’ institutions and institutional arrangements in contexts within a service ecosystem (Vargo & Lusch, 2016). Lusch and Vargo (2014) defined service ecosystem as a “*relatively self-contained, self-adjusting system(s) of resource-integrating actors connected by shared institutional arrangements and mutual value creation through service exchange*” (p.161).

- **Method for resource integration in service ecosystem**

The issues of resource integration in service ecosystems need to be addressed to enhance value co-creation. The key issues of resource integration are how to identify the most relevant resources for a particular situation/context; and how to bundle the most relevant bundles of resources for the beneficiary. *In order to address the first issue, we could apply an ontology engineering methodology for ontology structure construction and analysis* (Ma et al, 2014). Fensel (2001) defines ontology as “a formal representation of knowledge as a set of concepts within a domain, and the relationships between those concepts”. These concepts could represent knowledge of different groups in the domain, from experts to ordinary people. These terms and their relationships also form a complex network, a ‘concept’ network. The ontological structure analysis includes identifying the “roots” – the key concepts representing the network; clarifying links between other domain terms/concepts and the “root” concepts; clustering these concepts into conceptual clusters that describe the root concepts; then drawing the boundaries of these clusters.

In order to address the second issue, first, we need to analyze resource integration in the service ecosystem through modular structure analysis to identify the resources for a shared goal/outcome. Thus, the modular structure could enable the identification competences required for performing service (service here is in S-D logic sense) among actors in the ecosystem. Through modular analysis and ontology structure, connections of competences/operant resources between actors could be understood. Competences of all the potential actors would provide action opportunities and relieving/enabling possibilities for individuals for a variety of heterogeneous contexts. These actors would potentially enable the bundled competences to cope with the variety/heterogeneity of contexts. Of course, the exercisability of these action possibilities depends on the competences of other actors/entities in the service ecosystem in contexts. Second, the network is subject to further analysis and a list of bundles of actors and competences could be produced. As discussed previously, ontologies entail concepts and terms representing the competences/knowledge in a domain. Concepts/terms and the relationships between these terms form a complex network, i.e. a 'concept' network. This analysis can result in the development of an ontological structure with tight connectivity (rich relationships) of all competences, and yield weight differences between the relationships. Then, in order to achieve maxim resource integration, the resources from different actors would be compared by the beneficiary. The beneficiary becomes the resource integrator and he/she uses the operant resource and act upon other resources for value co-creation.

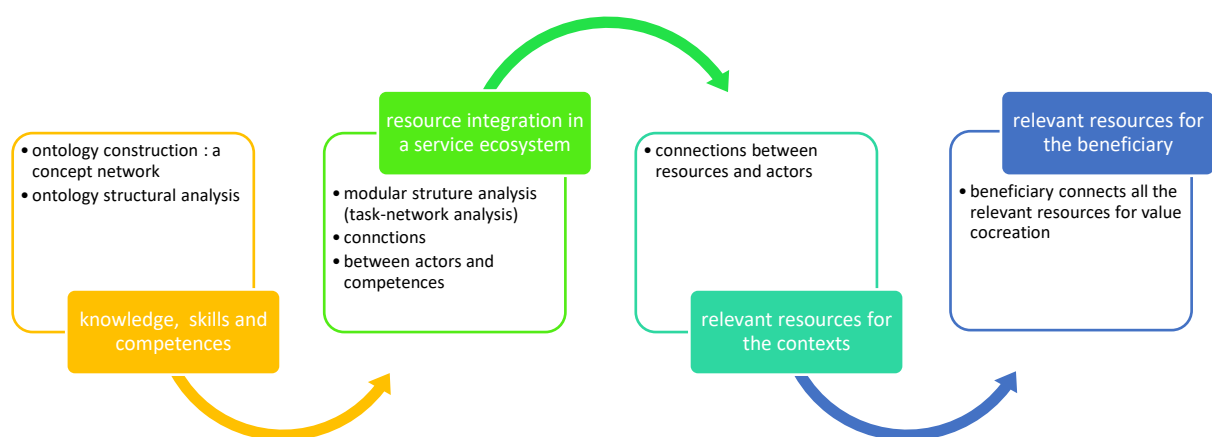


Figure 1: method for resource integration in a service ecosystem

AIM AND OBJECTIVES

Our paper aims to address challenges for constructive alignment in module design by applying the concept of co-creation in particular resource integration from a service ecosystem perspective. We proposed a method to enhance alignment between student learning outcomes, module content and the skills required by the marketing simulation.

METHODOLOGICAL APPROACH

A case study method would be adopted in our study. Case study method has been used in business research such as co-creation in innovation (Perks et al., 2012). It is suggested that case study would allow researchers to investigate micro-level activities (Perks et al, 2012), dynamic phenomenon unfolding over a period of time (Eisenhardt, 1989), deep understanding of the contextual setting (Yin, 2003). Case study method is well suited into largely exploratory and explanatory research *designed to extend earlier conceptual work and case study research* (Ellram, 1996, p.102). It is suggested that “*a more common application of a case study research is to build theory that can then be tested using further case studies, survey data, or another relevant method*” (Ellram, 1996, p.97). Our research would be undertaken to conceptualise value co-creation in collaborative service network practice implemented in module design at WMG. Our goal is to educate and ease the implementation process of other organizations interested in the application of collaborative service innovation network in education. We would develop a framework, which could be validated by further cases, surveys.

APPLICATION IN PROGRAMME DESIGN

The method of resource integration in a service ecosystem could be employed in the module design process. The process could be summarised as follows:

1. Identifying the knowledge and skills required through reviewing strategic marketing as a domain. As a team, we did the initial screening and identified the concepts, models and theories in marketing (ontology construction). We then identified the connections and

relationships between these concepts, models and theories by following some established marketing strategy process and model.

2. Deciding the key tasks and the key learning outcomes from Strategic Marketing Module, which is producing a strategic marketing plan based on the brands they created in the simulation game. The learning outcomes are the tasks for us to conduct the task network/modular analysis. In this analysis, the sub-tasks and sub-goals are further divided. All the relevant actors (human and non-human) are listed and the resources/competences/skills for conducting these tasks and subtasks for the goal /outcomes are identified. The connections, and interactions/exchanges between these actors including the tutors, the students, and the simulation game are analysed.
3. Based on the analysis, the content of the lectures, seminars, the marketplace briefing for the simulation game were designed and delivered.
4. The students engage in the teaching and learning activities and are equipped with the competences/skills required for co-creation and generate the outcomes which could be assessed by their PMAs.

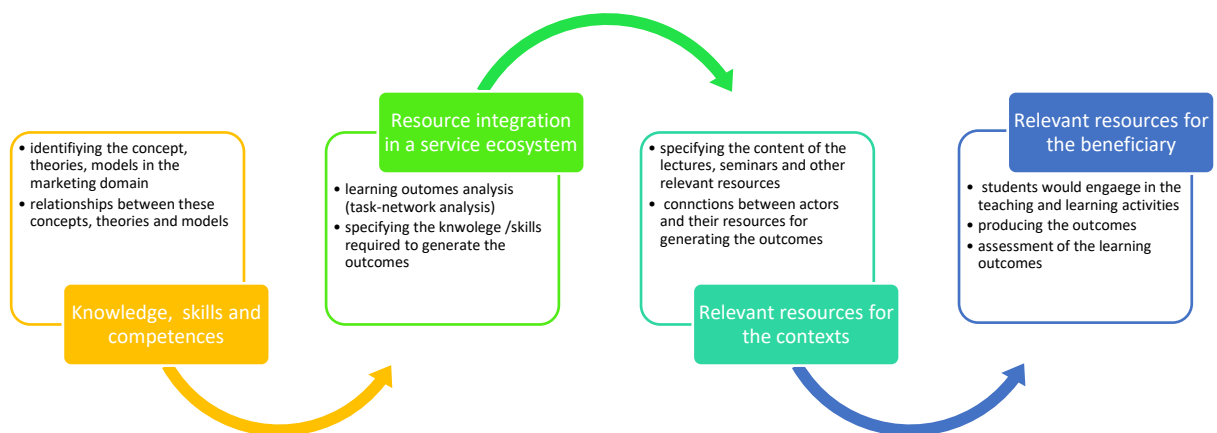


Figure 2: Learning outcome-based module design

DISCUSSION & CONCLUSION

This paper addressed challenges for constructive alignment in module design through the development of a process for module design from service ecosystem perspective. This process could enhance learning outcomes through improving the efficiency and effectiveness of exchange of information and knowledge among actors in a service ecosystem. This could be achieved by enhancing the level of resource density through facilitating easy access to appropriate resource bundles for learning outcomes. With the aid of process, we could identify who these actors are; how and why these actors are involved; what resources become; and how and why such resource integration occurs for high resource density for optimal learning outcomes.

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Interdisciplinary Research Methodologies in Engineering Education Research

David Reynolds ^a & Nicholas Dacre ^b

^a University of Warwick; ^b University of Southampton

David.Reynolds@warwick.ac.uk

KEY WORDS: Interdisciplinary, Research, Methodologies, Engineering, Education

ABSTRACT

As Engineering Education Research (EER) develops as a discipline it is necessary for EER scholars to contribute to the development of learning theory rather than simply being informed by it. It has been suggested that to do this effectively will require partnerships between Engineering scholars and psychologists, education researchers, including other social scientists. The formation of such partnerships is particularly important when considering the introduction of business-related skills into engineering curriculum designed to prepare 21st Century Engineering Students for workplace challenges. In order to encourage scholars beyond Engineering to engage with EER, it is necessary to provide an introduction to the complexities of EER.

With this aim in mind, this paper provides an outline review of what is considered 'rigorous' research from an EER perspective as well as highlighting some of the core methodological traditions of EER. The paper aims to facilitate further discussion between EER scholars and researchers from other disciplines, ultimately leading to future collaboration on innovative and rigorous EER.

INTRODUCTION

There is a perceived “skills mismatch between what engineering graduates possess and what is demanded by industry and potential employers” (Bubou et. al., 2017). Therefore, to prepare 21st Century Engineering students for the reality of the workplace, an Engineering curriculum should also include business-related skills such as Marketing (Rammant, 1988), Project Management (Dacre et. al., 2019; Pons, 2015) and other ‘soft’ skills (Wilson & Marnewick, 2018) or “professional competences” (Carthy et.al., 2018). This provides a particular challenge for academics from within these business-related disciplines who may wish to conduct Engineering Education Research (EER). As is the case with many EER scholars, many of these academics will be under-resourced and will be conducting education research part-time (Shawcross & Ridgman, 2013). Hence, they are likely to focus on EER areas in which they have an intrinsic interest (Nyamapfene & Williams, 2017) and due to familiarity, they may simply apply the traditions and approaches of their ‘home’ discipline rather than those of EER (Borrego & Streveler, 2015). If the traditions of their ‘home’ discipline are significantly different to the traditions of EER this may lead to issues when attempting to disseminate any findings in more traditional EER outlets.

Despite a rapidly growing body of literature, EER is still considered an emerging field of enquiry (Borrego & Streveler, 2015; Liu, 2019). Unsurprisingly, in the early stages of emergence, there is significant debate regarding the many possible epistemological, ontological and methodological approaches that could be applied to EER (Borrego et al., 2009); Borrego & Bernhard, 2011). It has been documented that there are often epistemological tensions among EER scholars (Cicek & Friesen, 2018) and these are likely to be further strained by the introduction of academics from different disciplines and traditions. It is beyond the scope of this paper to provide an in-depth analysis of the various approaches currently used in EER. Instead, it is the authors’ intention to highlight some of the main frameworks and models applied to EER in order to encourage discussion about how to embed pedagogic research related to business-related skills within the burgeoning traditions of EER. The authors also hope that this paper will encourage the collaboration between engineering faculty and social scientists necessary to allow EER to contribute to learning theory (Streveler & Smith, 2006).

WHAT IS RIGOROUS EER?

Just as Engineering is viewed as a scientific discipline, many definitions of rigour in EER can be traced back to definitions of rigour in scientific education research (Streveler and Smith, 2006). Moreover, there appears to be a general consensus among scholars of EER that science education research (including EER) should look beyond simply examining methods of improving the practice of teaching in class (Fensham, 2004; Lattuca & Litzinger, 2015). Instead, to be recognised as a discipline in its own right EER should also aspire to contribute to both theoretical and conceptual developments about how students learn Engineering (Streveler and Smith, 2006; Borrego and Streveler, 2015). Based on an initial review of the relevant literature, this means EER research should be:

- 1) Problem-led, hence requiring empirical investigation (Shavelson & Towne, 2002; Borrego and Bernhard, 2011; Bernhard & Baillie, 2016; Malmi, et al., 2018).
- 2) Informed by (and inform) both relevant educational theory *and* discipline specific theory (Shavelson & Towne, 2002; Streveler and Smith, 2006; Borrego and Bernhard, 2011; Bernhard & Baillie, 2016; Malmi, et al., 2018).
- 3) Method-led, meaning the methods used must be consistent and relevant to the question being investigated (Shavelson and Towne, 2002; Borrego and Bernhard, 2011; Bernhard & Baillie, 2016; Malmi, et al., 2018).
- 4) Systematic, explicit and provide a coherent and explicit chain of reasoning (Shavelson and Towne, 2002; Malmi, et al., 2018).
- 5) Presented in a way that allows it to be open to professional scrutiny and critique by both academics and practitioners (Shavelson & Towne, 2002; Borrego & Bernhard, 2011; Borrego & Streveler, 2015; Bernhard & Baillie, 2016; Malmi, et al., 2018)

As should be apparent from the above, despite its scientific origins, EER is more generally viewed as interdisciplinary in nature (Malmi et al., 2018). Hence while the above is an attempt to define what rigorous EER *is*, academics from business-related disciplines wishing to conduct

EER would also benefit from a framework to assess if their research would be viewed as rigorous by the EER community. Recently, Borrego and Bernhard (2016) offered a “tentative quality criteria” for qualitative EER research. This criteria was separated into three parts: Quality of the study in general; Quality of the Results; and Validity of the Results. They claim this set of criteria is consistent with other lists of criteria, including those from the *Journal of Engineering Education* and the *European Journal of Engineering Education* (Borrego and Bernhard, 2016). It could also be argued that these criteria should be applied to EER in general and are just as relevant to quantitative, constructive and mixed-method research.

Despite widespread agreement regarding the need for rigorous EER, what does appear to be open for debate is how “generalizable” the findings of EER need to be in order to be considered worthy/rigorous. Some academics argue that “generalizable” is an essential criteria of all scientific research and hence the same should apply to EER (Shavelson and Towne, 2002; Malmi, et al 2018; Streveler and Smith, 2006). However, others such as Bernhard & Baillie (2016) argue that EER is “situated in international and interdisciplinary contexts” and hence results may not be “generalizable/transferable to other contexts (disciplines and/or countries)”. Regardless, it is clear that there is a need for academics wishing to conduct EER to make explicit the underlying epistemological and ontological perspectives of their research.

WHAT IS CONSIDERED APPROPRIATE EVIDENCE IN EER?

It has been suggested that the nature of higher education student experience is related to the methodologies employed by higher education researchers (Khan, 2015). Furthermore, in order for EER to be effective in identifying ways to improve engineering education it should be learner-centred or student-centred (Catalano & Catalano, 1999) and requires “multiple epistemic frames” (Riley, 2014). In fact, in their study of 155 EER papers, Malmi et al. (2018) identified 128 different explanatory frameworks. Therefore, based on the work of Bubou et al. (2017), the purpose of this section is to introduce the three most popular traditions currently being applied in EER in order to give scholars who are new to this field a number of options from which to position their own research.

Bubou et al. (2017) identified three traditions within EER: Discipline-based education research (DBER); Scholarship of Teaching and Learning (SoTL) and Evidence-Based Teaching (EBT). The oldest of these traditions, the knowledge base of DBER, has been built in over 30 years (Bubou et al., 2017). This tradition tends to emphasise improvements in the *practice* of teaching, usually focussing on a specific topic. See also the work of Hutchings & Shulman (1999) into “effective teaching” and “scholarly teaching” (cited in Borrego & Strevler, 2015). Research based in this tradition may be viewed as “teacher-centric” rather than “student-centric” (Hamer, 2006; Pears et al., 2016) with an emphasis on identifying how to best ‘transfer’ teachers’ knowledge to students.

This approach encourages the use of experimentation and comparative studies, using changes in student grades and attendance as evidence of change. This is not intended as a criticism, as research using this framework is clearly important for the development of teaching ‘best practice’ and DBER has been widely published in science research journals including proceedings from the National Academy of Science (Bubou et al., 2017).

In contrast, SoTL emphasises student-centrality, and encourages the systematic investigation of student learning as a concept (Bubou et al., 2017). SoTL research embraces discussion and critique beyond the classroom, but also tends to be topic-specific (Borrego & Strevler, 2015). As a result, researchers within the SoTL will often use discovery and reflection as sources of evidence (Bubou et al., 2017).

The last tradition, EBT, could be viewed as an attempt to bridge the gap between DBER and SoTL. Inspired by Evidence-Based Medicine, EBT encourages the the collection, analysis, and interpretation of information about students to inform teaching and learning for better outcomes for the education system as a whole (Bubou et al., 2017). See also “data-based decision making” in Education, such as the work of Škėrienė and Augustinienė (2018). EBT is based on social constructivist learning theories, the science of learning (learning sciences), and teaching/learning styles (Bubou et al., 2017). As a result, EBT research tends to encourage the use of a wide variety of “emerging” (usually qualitative) methodologies including Case Study, Grounded Theory, Ethnography, Action Research, Phenomenography, Discourse Analysis, and Narrative Analysis (Case and Light, 2011).

CONCLUSIONS

The authors of this paper agree with Borrego et al. (2009) who state that “no particular method is privileged over any other”. However, standards of rigour in EER must be maintained. Bernhard & Baillie (2016) warn that “An unhealthy overemphasis on either [problem-led or method-led research] can lead to a lack of quality”. This is particularly important when conducting interdisciplinary research. It is also important when engaging with models and theories which investigate factors that influence learning beyond what occurs in the classroom (Streveler and Smith, 2006). For example, investigations into encouraging wider student engagement and the development of engineering curriculum appropriate for the needs of both engineering students and the organisations which will eventually employ them (Lattuca and Litzinger, 2015).

Streveler and Smith (2006) argue that rigorous EER should contribute to learning theory, rather than merely being informed by it. However they also claim in order to achieve this aim, it is necessary to foster partnerships with “psychologists, education researchers, or other social scientists” (Streveler and Smith, 2006). We propose that in order to effectively introduce researchers from these disciplines to EER, it is necessary to highlight the underlying epistemic, ontological and methodological traditions (and debates) within this discipline. It is our hope that this paper will serve as an introduction to some of the terminology, frameworks, and models in EER. For researchers seeking more detailed discussion about these traditions and recent developments within EER, we direct readers to the sources used within this paper, but most significantly the comprehensive *Cambridge Handbook of Engineering Education Research* (Johri and Olds, 2014).

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The Value of Business Simulation Games to Enable Students to Acquire the Key Skills Employers Require

Pontin, David Adigun, Lydia
WMG, University of Warwick

David.Pontin@warwick.ac.uk

KEY WORDS: Simulation: Employability Skills: Project Management Game: Gamification of Learning: Project Management Realities

SUMMARY

How do students gain useful real life work experience without a real life work experience? How can the skills employers say they need be learned in the classroom? These skills include effective communication, team skills, problem solving and critical analysis, motivating others, ability to work across different cultures, ability to have difficult conversations, ability to reflect and self-awareness (CMI 21st Century Leaders research). Business simulation exercises go some way to squaring this difficult circle combining hard technical skills with soft interpersonal skills within a realistic commercial setting simulating the interconnectedness, dynamic and messy nature of real life. They also provide a safe place where participants can afford to fail first before getting it right or better. The authors (academics and practitioners) present 2 examples from the Project Management disciplines outlining principles and experience to date. Strengths, weaknesses, challenges and possible developments areas are discussed. Future research is proposed and in particular data capture drawing on the present and past student population within the authors teaching portfolios. This practice paper therefore also invites suggestions and collaborations from interested parties to further develop this potentially powerful learning experience.

INTRODUCTION

There are several challenges that face students wishing to acquire the project management skills, tools and techniques that employers want. Outside of a real life industrial or commercial experience these challenges become more acute for both students and educators. Theories, current best practice, the body of knowledge and the evolution in thinking can all be explained adequately in the classroom or lecture theatre. Case studies can provide context and examples of good or inadequate application. Knowledge is useful but without application its value is not realised (Boyer 1990).

Therefore knowledge needs space, and a safe space, where practice and application can help students to grow in confidence and mature their judgements of the trade-offs that describe the distinctive nature of project management.

Project or business simulation games can provide this space and opportunity. In addition they enable students not only to think about good solutions but also feel the emotional roller coaster experience typical of real life projects. The coming together of all of these aspects in real time best describes modern projects and help students therefore to develop not only hard technical project management skills but also the soft interpersonal skills that equally play a significant part in successful project delivery. This practice paper describes work in this area highlighting the value but also difficulties and possible future development.

LITERATURE REVIEW

One of the skills employers expect graduates to possess is technical skill, but not rated as high as having the ability to work effectively in a team, make decisions, possess problem solving skills and communicate effectively (Forbes, 2014). Over the years this requirements do not seem to change as CMI (2018) confirms these expectations of employer as graduates are rated high in possessing skills like digital technologies, financial skills, project management, and maintaining network but score really badly with skills like “having difficult conversation and managing people” which reveals huge issues around interpersonal skills, communication skills. CMI (2018) also highlights the ongoing debate about improving employability is centred on graduates having

professional management skills. It is no surprise that 85% of employers expect graduates to have some work experience while students believe the main obstacle to acquiring a role as a first-time manager is having enough experience. The way employers rate graduates goes a long way to show that there is a gap in the skills students acquire and the ones most needed for them in the workplace.

Project management is relevant to all organisations, which has led to a higher demand for a well prepared project manager (Hartman et al., 2013). Therefore, it is important for Higher Education to incorporate a transformative and innovative learning environment that encourage students to build up on these skills and meet up with the dynamic environment of the workplace through “play-based approach” (Smith, 2019).

Incorporating simulation in the syllabuses provides innovative methods of learning as a way participants learn through designing a learning strategy and support their mental model by playing the simulation or game (Rokooei, 2017).

A number of studies have confirmed that the benefits of simulations result in enhancing student confidence and employability which include developing team working skills, encouraging active learning, cost effective method compared to real life project, self-awareness and risk free environment to ensure experiments on decisions made with no consequence which is opposite to the real life environment and allows participants see the consequences of their behaviour (See for example, Avramenko (2011); Zwikael and Gonen (2007) ; Bellotti et al (20145); Hartman, Watts and Treleven (2013).

Project management students are able to gain valuable insights by playing the simulation and are to achieve an increased understanding and apply project management concepts in a dynamic responsive situation. However, some deterrents were identified - the over gamification of learning (Avramenko, 2011,) inability of the game training students to work as a team, most games focus on the planning phase of the project and do not include other real life events, very few games focus on unexpected risk events.(Zwikael and Gonen, 2007). There are also a limited number of project management simulation applications.

Rokooei et al (2017) also identified how important it is to design and establish Project management simulation that covers every aspect or area of project management. Designing a simulation game begins by having a well laid out pedagogical goal which is clearly outlined. The other major steps included the interactive elements of the simulation, participants, feedback types and challenge design (Gutl, 2015).

Misfeldt (2015)-used a “scenario based education model” as a way of how students relate to the different knowledge domains. This included the integration of disciplinary domains, specialised domain, and scholastic domain. Furthermore, according to The Boyer commission (1998) technology should be used to enhance teaching and that of ones colleagues with focus on how these technologies enhance teaching and in turn might have a positive outcome on student learning. It was made very clear that technology or innovation should not be used to replace teaching but to enrich it.

AIM OF THE INTERVENTION DISCUSSED

The intervention was aimed to enhance students’ employability skill using simulation that connects to real life situations.

DESCRIPTION OF INTERVENTION / PRACTICE

The first example comes from a management of risk module for post graduate full time students at a UK University. The module is a core module for those doing project management but also a popular option for other management and policy masters’ students. The student cohort is largely international and the broad mix of disciplines provides useful diversity to represent typical project teams. The exercise involves creating a risk register for a project at the start of the project and then updating and maintaining the register during the full life cycle of the project. The project is an EPC (Engineering Procurement Commissioning) project concerning a steam turbine for a new build coal fired power station in South Africa. Information about the project scope, organisation, contract conditions, budget and a high level Gantt chart (timeline) was provided. Groups of 5 or 6 formed project teams and were required to analyse the information,

brainstorm and identify risks. Then prioritise the risks by considering probability and impact and then develop mitigation plans against the top priority risks. The completed risk register was then presented to the other groups within the seminar for group comment, scrutiny, debate and discussion.

The subsequent 2 seminars represented different times on the project timeline. Events had occurred and the groups each self-assessed their mitigation effectiveness. Updates to the risk register were also permitted as new information became available or new thinking developed.

The second example comes from a foundational project management module at another UK University again core to those doing project management but optional for other MSc streams. The simulation of a project is spread over 3 days of a 5 day block teaching format. The full project lifecycle is covered with project groups formed by the tutors considering individual Belbin self-assessment and starts following a project brief with comprehensive planning followed by project execution. Data is entered into a computer programme which calculates progress considering the project plan, resource allocation and risk strategy as applied by supplier choice. Full reports are also produced at period ends including daily reports, percentage complete on tasks, earned value curves and options for adapting the original resource plan in light of the most recent information.

EVALUATION OF INTERVENTION

The first example was useful for introducing students to the realities of project management and in particular having to make decisions quickly sometimes with incomplete information. As most of the students had no experience of risk management and many no work experience some complained about lack of subject knowledge. However this forced students to fully explore the knowledge within the group and also other creative solutions including the brainstorming of possible scenarios. The presentation in English (a second language for most students) with minimal time to prepare was challenging for many but however helped to develop a vital skill required in the workplace and in life in general. If the safe environment was created and maintained the majority of students embraced and took this opportunity and feedback was positive.

The second example has some similarities with the first but the intervention is greater in terms of both breadth and depth. The briefing for the game takes 45 minutes which with 38 slides highlighting some key information and presenting the overview. The first day includes 5 hours scheduled to analyse the information and develop the plan or schedule, resource allocation, initial supplier choices and budget. Many teams run on further into the evening. Subsequent days involve the execution of the project where each team must book resources, allocate and prioritise work, make supplier choices and respond to events, failures and other issues. This execution represents the full life cycle of a typical project and ends with project completion where performance against objectives in terms of time, cost and profit are assessed.

DISCUSSION

- Is the Game Realistic?

The second example is reasonably realistic of a typical project scenario. It is sufficiently complex with a mix of different tasks presented within a network diagram. In this sense the logic of the schedule is given. The work also includes a mix of work carried out in-house and that sub-contracted out to the supply chain. With various suppliers this is where the risk approach can be applied. The context of the project is explained but only lightly and the descriptions of work could be applied to multiple sectors. In this sense the advantage of sector knowledge or experience is removed and the pure project management techniques are tested. The complete project life cycle is represented over the 4 days but effectively compressing a 7 month project. This is considered an acceptable compromise within the constraints of the 1 week module.

- Does the Game Enjoy Good Student Engagement?

The second examples demonstrates remarkable student engagement. It sits within a 40 hour teaching block approach with the game starting on day 2 with the initiation and planning phase. Tutors often have to accelerate the pace and pressurise team decision making to obtain the team plan and budget with many teams running over the 6.30 pm finish time until in some cases a 7.30 finish. At the end of a 9.5 hour intensive working day this demonstrates the commitment and engagement of the students. It is also representative on real life project situations. Even

students with previous work experience comment on the “hurting head” but show relief as they submit the plan and objective for the day.

- **Does the game help develop the skills that employers say they need?**

One of the challenges of project management is not the individual knowledge areas and various tools and techniques. Many would argue that these are relatively straight forward and can be understood in isolation fairly easily. What is more difficult is the judgement for what tool, technique or approach might be the best suited or more effective in a given situation and managing all the breadth and diversity of situations that arrive during the execution phase and often inconveniently all at the same time. Managing the “heat of the battle” is what can be demanding. These games can simulate the real life chaotic and often messy nature of real project management. Students should have sore heads if we are to try and explain what it is like in real life and prepare them to be effective in this environment.

The planning phase starts with application of what some would describe as “hard” technical skills like critical path analysis, scheduling using Gantt charts, resource allocation and levelling, risk analysis, cost optimisation and project strategy. Working within a diverse group designed with a useful blend of Belbin role types tests and develops “soft” or people skills and allows application of team development theory (Tuckman). The executions phase further tests these skills introducing uncertainty, review of decisions when outcomes differ from those expected requiring teams to adapt to the fast changing and most recent information. Such event also encourage self-evaluation therefore introducing the concept of the reflective practitioner.

- **How can we capture more from this learning experience?**

The game concludes the Thursday evening with performance in terms of project delivery date and profit, the 2 stated project success factors. Teams arrive at the end of an emotional roller-coaster with a variety of emotions again demonstrating the commitment and engagement. Team presentations analysing their performance and key learning concludes the module along with further performance feedback and briefing on their individual post module assignments. This is where there is potential to mine more of the rich experience the simulation game has generated. The challenge is how to capture this in real time without affecting the flow so it can

be retrieved later. This is an area where thought and reflection is required and could be the subject of future research.

CONCLUSIONS & RECOMMENDATIONS

Business and project management simulation games if carefully designed can be realistic of real life situations and feedback from students and the high level of engagement supports the view that that this can be an effective tool for teaching and learning. This also fits the current thinking and trend in active learning. The situations does create scenarios and a safe place where the skills that employers say they need can be acquired and observations during teaching and review of individual post module assignments do support this claim. However critics point to the lack of scientific evidence to confirm skills transfer and more specific the level of skill transfer to the workplace (Romero et al 2015). Therefore there is a need for empirical studies to bridge this gap. To do this there is a need for tools to be developed to capture points of interest during the “heat of the moment” allowing post project simulation reflection and deeper understanding between behaviours, events, impact on the team and team performance. Such tools could be also be useful for practitioners to support the objective to become “reflective practitioners”.

Future research could also include longitudinal studies of post students to understand their view of the significance of such learning with greater time and experience in the workplace.

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Internationalisation: Beyond Professional Competencies and Learning Outcomes in a Changing Landscape

Olson, Nancy and Reynolds, David

WMG, University of Warwick

Nancy.Olson@warwick.ac.uk

KEY WORDS: Professional Competencies; Cultural Intelligence; Project Management; Simulation; Employability Skills;

SUMMARY

Much has been written about the changing global environment and the increasingly volatile, complex, and uncertain context facing many industries and organisations as they try to adapt. The ability to work in multi-cultural project teams, with a wide ranges of diverse, multi-disciplinary stakeholders is an increasingly important capability sought by employers and students undertaking further study and preparing for a professional career. Many graduates with a first degree in engineering, science or technology are undertaking MSc studies in project management as a way of enhancing their employment prospects.

This paper identifies gaps between the competencies and skills that organisations are seeking in this dynamic environment, the international project- professional competency frameworks (APM, PMI, IPMA, GAPPS) and the role that higher education and learning outcomes can play in preparing students for both their next position and careers into the future. It considers:

How do student gain experience in enacting and applying professional knowledge or competencies in complex multicultural contexts?

How can a learning environment be created which contributes to the development of these competencies?

Findings from 3 research investigations on the development of cultural intelligence and the use of cultural intelligence scales in multi-cultural project teams using project simulations and case-study role plays in education are briefly outlined and some of the key findings are discussed. Several reflections for educators seeking to create learning environments which support the development of the complex competencies and transferable skills sought by employers and students are presented.

INTRODUCTION:

Over the last 10-15 years there have been a number of studies which investigated the global engineering competencies required by industry and highlighted the need for student learning outcomes which more closely reflect the skills sought by employers in a dynamic and complex international environment (e.g. Ball et al., 2012, Allan and Chisholm, 2008; Jackson, 2010)

The interest in competency frameworks and their development or assessment links not only with learning outcomes and employability; but also with the need for programme accreditation and professional recognition in many countries (e.g. ABET, APM Chartered Project Professionals). Learners on professionally orientated higher degree programmes may also have career aspirations for chartered status.

The need for multi-disciplinary competencies is also highlighted by the Project Management Institute who estimated that 15.7 million new project management jobs will be added globally, across 7 project intensive industries by 2020 with an economic impact of over \$US18 trillion (PMI, 2010). Studies in the UK also emphasise the growing demand for project management skills and competencies (FoPM, 2017) with reports indicating that over one third of organisations cited project management competencies and skills shortages as a barrier to their future development, These organisations employ over 2.13 million full-time workers in the UK project management sector and the profession generates £156.5bn of annual gross-value-add (GVA) about 9% of the UK total (APM and PwC Research, 2019).

Graduates from a wide variety of engineering and science related disciplines are returning to further study with particular emphasis on increasing their career prospects. This trend is also increasing internationally with the Higher Education Association finding that international

students constitute nearly 48% of PG students in science, engineering and management (STEM) subjects and that 66% of all full-time taught postgraduate students (Ryan and Pomorina, 2010). Over 75% (HEA) of international students in the UK cite employability as their primary motivator for further education. This is further supported by students enrolled on one UK University MSc project management programme, 82% of whom indicated that employment/career development was their primary reason for returning for choosing this course.

The paper reports on three studies in an educational context which examined the relationship between project professional competency frameworks, the development of project skills and teams using project simulations exercises and case study/role plays, and the development of multicultural competencies and skills.

LITERATURE REVIEW

In a study of the global competencies that multinational companies prioritise when making hiring decisions for engineers, Striener, Villa-Parrish and Warnick (2015:1250) found that the competencies reported as most valued by hiring organisations were the ability to: (1) Identify risks and formulate plans to mitigate risks; (2) Design a system, solution or process to meet desired outcomes; (3) appreciate and understand different cultures, (4) work on international teams, (5) communicate cross-culturally. Their research supported the argument that these global competencies are viewed as critical by employers with specific emphasis on appreciating and understanding different cultures and working and communicating in international teams.

The International Project Management Association (IPMA, 2015: 5) defines individual competency as *'the application of knowledge, skills and abilities in order to achieve the desired outcome'* and differentiate this from team competencies; *'the collective performance of individuals towards a purpose'* and organisational competencies, which address *'the strategic capabilities of a self-sustaining unit of people'* (ibid: 18)

An examination of the leading project professional competencies frameworks,(i.e. APM, PMI, IPMA, GAPPS) and related academic literature (e.g. Pellegrinelli, 2008; Crawford, 2005; Turner and Muller, 2010) surprisingly revealed that despite eschewing a 'global outlook' and the international nature of the project/programme management profession that none of the

frameworks specifically or directly referred to competencies associated with international or multi-cultural project teams or multi-cultural competencies. Although, for example, it could be argued that in the IPMA Framework (2015) this could be an unspecified subset of the perspective of 'context' and the competence sub-element of the cultural and values of the organisation, this is not explicit.

Muller and Turner (2010) investigated the relationship between successful project managers (i.e. a track record of successful project delivery) and leadership competencies across a range of different project types. Their study profiled the intelligence (IQ), managerial (MQ) and emotional competencies (EQ) of 400 project managers globally and found that successful project managers exhibited high expressions of one IQ sub-dimension (critical thinking) and 3 EQ sub-dimensions (influence, motivation and conscientiousness) across all types of projects and industries. Despite being an international study of global project managers, the study did not investigate the role of cultural intelligence (CQ). Several studies (e.g. Halverson and Tirmizi, 2008; Van Dyne et al., 2009) provide evidence and argue that cultural intelligence is a different competency or skill that goes beyond emotional intelligence.

Cultural intelligence can be understood as the ability to work effectively across multiple or different cultures. Ang (2006) defines it as '*an individual's capability to function and manage effectively in a culturally diverse setting*'. The CQ measure is based on 4 dimensions or capabilities: the metacognitive, cognitive, motivational and behavioural capabilities to adapt to different cultures. Although there are many definitions (e.g. Earley, and Gibson, 2002; Earley and Ang, 2003), Earley and Mosakowski, 2004; Halverson and Tirmizi, 2008; Ng, Van Dyne et al., 2009; Thomas and Inkson, 2009) the definition offered by Peterson (2004) is adopted in this paper:

"Cultural intelligence is the ability to engage in a set of behaviours that uses skills (e.g. language or interpersonal skills) and qualities (e.g. tolerance for ambiguity, flexibility) that are tuned appropriately to the culture bases values and attitudes of the people with whom one interacts"

Whilst the study of cultural intelligence is gaining considerable interest and attention in the wider management fields, there is a gap in the published studies in the project management field and literature. The following sections report on 3 studies which examined the use of cultural

intelligence scales (CQS) in the development of MSc Project Management students and multi-cultural project teams.

CONTEXT: THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

- Aim of the intervention discussed

To investigate the challenge(s) of fostering a learning environment that contributes to the development of intercultural competency in complex professional domains and multi-cultural project teams:

How do students gain experience in enacting and applying professional knowledge or competencies in complex multicultural contexts?

How can a learning environment be created which contributes to the development of these competencies in an international context?

DESCRIPTION OF INTERVENTION / PRACTICE

This paper outlines and discusses 3 of the studies influencing the development of learning intervention. The first study focussed on post-graduate students (both full and part-time) enrolled on a module which is core on the project and programme management (PPM) degree stream but is also offered on a wide range of 13 other post-graduate management related programmes including engineering business management. The module is delivered in 7 centres in various countries around the world. 80-90% of students are predominately from 10 countries, but the various degree programmes available have included students from 27 countries world-wide.

The module employs a project simulation in which students work in syndicate groups of 5-6 and are challenged with delivering an engineering design, build, test 'project' according to pre-defined criteria within a specific timeframe The week-long exercise involves developing an initial

project plan and throughout the simulation students monitor the “actual” results generated by the simulation for 7 periods (months) against plan; and if necessary take corrective action to meet the project objectives within the stated constraints and parameters.

The study /intervention employed the use of a questionnaire which included a modified cultural intelligence indicator. This was made available to students (119 students in 12 syndicate teams across 3 module occurrences) online before the module and students were asked if they would be willing to participate in completing the questionnaire and indicator and semi-structured interviews at the end of the exercise. During the simulation exercise, teams were observed and notes taken using participant observation techniques. Post- module each student was electronically given the results of their individual cultural indicator scores, plus generic descriptions of each of the elements. Post-pilot this communication was extended to include some techniques for enhancing or developing various aspects of cultural communication and some sources of further reading. Semi-structured interviews were conducted with 37 students following the exercise.

The second investigation extended the study into another core project management module which has an advanced version of the engineering project simulation exercise involving the management of multiple (6) projects. In this module the emphasis is on planning and control of a portfolio of engineering projects represented by multiple instances of the initial project simulation. The module is core for the PPM MSc and is not offered to other degree students as an elective. This study included 54 participants (49 respondents) from 19 different countries who formed 8 teams across 2 module instances. The additional characteristics of each team were noted as well as observations of the team interactions and team roles adopted during the game. In addition to the CQ self-assessment, a 2nd round of peer-assessed CQ was also conducted.

The 3rd study extended this work into more uncertain and complex contexts with students on a 3rd PPM module which is also core to the PPM degree and is a popular option with students on other programmes (e.g. Engineering Business Management). Students on this week-long module work in multicultural syndicate groups on a complex case-study which involves role-playing as a ‘project professional’ in a multinational manufacturing organisation with stakeholders from a wide variety of specialisms. The emphasis in this module is on the early

stages of the project/programme conception/initiation. At the end of the module, students are then given the opportunity to present their recommendations to 'senior stakeholders' within the case study organisation.

EVALUATION OF INTERVENTION / PRACTICE

The initial study yielded some interesting and surprising results in that students reported that they found the opportunity to learn about their own cultural communication 'highly useful' (87%) and that learning to work in teams with colleagues from other countries was 'highly relevant' (92%) to their future career plans or aspirations. Demand for further information was so high that following the initial pilot study, the questionnaire feedback was extended to provide additional reading and resources for further self-study.

Studies 1 and 2 found that there was no statistical significance correlation or relationship between self-assessed individual or average team cultural intelligence CQ scores and project team performance on the engineering project simulation exercises. There did appear to be a relationship between student satisfaction with the game-simulation and higher self-assessed average CQ team scores.

During the 2nd simulations, 4 teams (across 2 modules) were observed and peer-assessments were also completed. Results suggest that individuals tended to rate themselves consistently higher than their peers did across the 3 main CQ dimensions and that peer-assessment of CQ may be more closely related to simulation game outcomes.

The composition of the teams and the extent to which they had a dominant (homogenous) nationality or were widely mixed (heterogeneous) was also noted as was their current degree programme.

In the 3rd simulation (case study/role play) the nature of the exercise changed. The 'problem space' was no longer based on an engineering project design-test-build simulation, but moved towards a complex, strategic programme of projects with emphasis on problem definition and problem solving. The case study presented a wide range of domain-specialist stakeholders, risk, complexity, volatility and ambiguity and the students developed their understanding of the case

study over the week long module via a series of formative learning exercises. The exercise culminated in some contextual changes and a final team presentation to the 'senior executives' (role-play) of the case study company.

DISCUSSION

The three studies and project simulation exercises could be viewed through the lens of understanding the exercise or simulation that the students engaged in. The first engineering design-build-test simulation the emphasis is on team-skills, planning, monitoring and control and the associated competencies map to existing professional competency frameworks.

The second simulation extends the simulation exercise into a complex, multi-project environment where the complexity of the problem and the team-work and co-ordination increase. Again, the learning outcomes map closely to several existing professional competency frameworks.

The 3rd exercise (case study and role-play) simulates the challenges associated with the early stages of the project programme lifecycle and the participants engage in defining the 'problem or opportunity' and agreeing as a team what approach should be taken. Contextual awareness of the situation is also required. Drawing upon the work of Grint (2008) the 2nd simulation could be classed as a 'critical problem' whilst the 3rd more closely approximates what his typology would class as a 'real-life' tame problem and with some teams, even a 'wicked' problem. The learning outcomes in this simulation reflect more advanced project management skills and programme management competency frameworks, but also extend this to incorporate aspects of working in multi-cultural project teams.

CONCLUSIONS & RECOMMENDATIONS

These 3 studies explored the use of CQ indicators in developing multi-cultural project team competencies in a series of project simulation exercises of varying complexity, volatility and uncertainty. Learner feedback on the use of the CQ indicators as a learning tool for the development of the complex skills and competencies was very positive. The work suggests that learners highly valued the opportunity to focus on this aspect of their professional development and students appeared to be highly motivated to continue studies beyond the classroom and

willing to engage in self-reflection to improve what they perceive to be skills and competencies which are of value to their future career aspirations.

The exercises provide exposure to authentic scenarios which simulate the 'real world' situations in a safe but challenging environment and provide opportunities to gain experience in complex multicultural project teams. The use of the indicators to 'foreground' the multi-cultural facets of the project teams and stakeholder engagement added another 'real-life' dimension to the work.

In experiencing these simulations learners are also given the opportunity to develop confidence (or self-efficacy), explore the development of valuing team and cultural diversity and to develop awareness of their own capabilities and on-going development needs.

Further studies and pilots are in progress to explore the use of MOOCs (e.g. MOODLE) to assist and support the use of the CQ indicator and peer-assessment processes and to incorporate elements of self-reflection. Work on these aspects is required to help create a wider sustainable learning environment and to enable the intervention to be scaled up for groups of 300+ students a year before the intervention can be incorporated into the MSc Degree and module learning objectives and assessments.

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Theme 6: Engineering Education & EER Workshops

Introduction

The WMG & School of Engineering 2019 EERN Organising Committee are pleased to introduce a set of workshops that will be conducted during the conference, designed to support teaching at higher education level. This introductory paper presents a brief overview of the scope of the workshop sessions.

Engineering higher education plays a crucial part in preparing the engineering graduates for their future roles. To match the ever evolving industrial needs, there is a growing emphasis on updating engineering teaching and learning techniques. Education has to change with changing times. In today's world, not only the industrial needs and demands are EVOLVING, but also the learning preferences of students are changing. To keep up with the demands, engineering educators have to be equipped with updated technological and pedagogical advancements and techniques. Training on a regular basis as well as discussion with peers in the field allows for improvement in current practice and also provides a safe space for sharing practices.

There are eight workshops being offered as part of the EERN conference. Each workshop session is designed to last for 90 minutes. The workshops are designed to cover a variety of themes including assessment, programme development, innovative teaching methods, research methods and well-being of educators. They are designed to be interactive, hands on activities to allow for maximum engagement and discussion. This is a great opportunity for educators in engineering higher education to learn from experiences of other members in the community and share their own best practice. The best way to go forward is to learn, share and collaborate.

Dr Maryam Masood, Teaching Fellow, WMG, University of Warwick.

Escaping Stale Practice in Engineering Education

Agg, Chloe, Catherine Hack

University of Warwick; AdvanceHe

c.agg@warwick.ac.uk

KEY WORDS: Engineering, Education, Escape, Play, Gamification

SUMMARY

Some elements of engineering education are traditionally taught, or embedded, through repetition, and as such, students and staff are not motivated to engage fully which can lead to issues with both learning and student retention. One means of addressing this is to increase the 'fun' through gamification, creating an inherent desire in the students to engage in the session through play.

Gamification is the application of game mechanics in a non-gaming context (Deterding et al., 2011) and has many recent case studies evidencing its use in increasing engagement and success rate. These range from call centres and conflict management to pizza delivery and new product launches. It has also been used successfully in various educational settings. As Lee and Hammer (2011) state; Gamification can motivate students to engage in the classroom, give teachers better tools to guide and reward students, and get students to bring their full selves to the pursuit of learning. With increased pressure to retain and satisfy students, it is unsurprising that there is a growing amount of research into the use of gamification in education. Hung (2017) explored this, reviewing ~10 studies, and finding a generally positive response from the students, though there was minimal evidence of impact on grade improvement. The discipline with the most consistent positive responses was computer science, which may relate to the student and staff's possible greater participation and interest in computer games, although there is not currently sufficient evidence to support this. A more recent systematic review of ~18 papers on game based learning in higher education by Subhash & Cudney (2018) found the same observed benefit of increased student engagement. However, they also found a stronger

correlation between gamification and increased student performance. This shows how rapidly gamification use and research is growing in higher education, with findings improving year on year.

Subhash & Cudney (2018) also identified that publications on gamification in higher education are seven times more prevalent in computer science than in mechanical engineering. Strong links between engineering and computer science/software engineering are known to exist, with students sometimes having similar traits and interest. It seems likely therefore, that given the same amount of research, engineering could enjoy the same positive student response to gamification as computer science. Current literature on gamification in engineering education is recent, minimal, and is generally focused on specific case studies, such as the use of leaderboards (Ortiz et al., 2019), web games (Wang & Abbas, 2018) & simulation (Hamzeh et al., 2017). These studies have all found gamification to improve either student engagement or understanding/performance or both.

With such a new area of research it is necessary that we build up a body of work through case studies etc. to enable future work in meta-analysis of outcomes to further substantiate the use of gamification in engineering education. As such, this workshop shares an “escape room” based methodology of gamification for creating more engaging practise sessions for engineering fundamentals. This, in addition to being of benefit to participants, will add to the case studies available for future analysis.

AIM OF WORKSHOP

This workshop is aimed at those who run practise sessions or tutorials for small cohorts of students, e.g. weekly maths tutorials. We will share ideas on how to create more playful ways of generating engagement in practise sessions, related to escape rooms, in order to improve student engagement, understanding and performance. The workshop will enable participants to experience gamification in action, to share their own experiences of gamification in engineering education, and to begin to create their own escape room based tutorials.

WORKSHOP SCHEDULE

Minutes 0-5 – Introduce the author, the session and its purpose.

Minutes 5-20 – Each table of participants will have the clues to solve one puzzle, which will enable them to unlock one padlock on a locked box at the front of the room.

Minutes 25-40 – Discussion about the participants experience of puzzle solving & unlocking the box. Further discussion relating this to the experience of students who are using this in maths tutorial sessions. Explanation of how the puzzles were created based on existing practise questions.

Minutes 40-55 – Participants have the opportunity to create their own puzzles based on their own practise questions with support from the workshop leaders.

Minutes 55-70 – New puzzles are transferred to the lock box, and passed onto other participants tables to solve; can the box be opened again?

Minutes 70-90 – Discussion of how participants might use this in their own practice and problems anticipated / experienced so far. Further discussion of what other gamification/play elements participants have used in their practice.

WORKSHOP OUTPUTS AND OUTCOMES

Participants will have the opportunity to experience gamification in education, from both the student and the teacher perspective. This will be specifically in relation to using escape room style puzzle solving to increase engagement in practise sessions. This will enable participants to make informed decisions about whether they would like to gamify their own curriculum. The workshop will also provide advice & guidance on how participants can create their own escape room style tutorials. Lastly, participants will have the chance to share their own experiences of gamification and play to create a broader discussion forum.

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Maintaining Healthy Wellbeing – A Workshop for Early-Career Researchers in Higher Education

Broadbent, Rebecca

Lamb, Julian

Aston University^a

r.broadbent@aston.ac.uk.

KEYWORDS: Wellbeing, Authenticity, Exhaustion, Staff Support.

SUMMARY

This workshop explores two key factors in maintaining healthy levels of well-being: authenticity and exhaustion.

Finding authenticity does not require time spent in a magical retreat on a mountain top. Instead it requires you to interrogate your everyday life and judge what makes you feel ‘comfortable and alive’ and that which makes you ‘uncomfortable and anxious’; this quiet, honest, personal judgement, can only be made by the individual (Rogers 2004). It is harder than you might think because we are all culturally conditioned to seek ‘money, promotion and status’ as a universal measure of success (De Botton 2005). We do not suggest that these should be avoided, but rather these should not be assumed to be required to be high on the list of considerations when deciding what direction you want your work life to take. There are many professionals who have blindly pursued a role or position that, deep-down, makes them feel uncomfortable and anxious despite the more obvious rewards.

Exhaustion can be a common experience in any profession. Working in Higher Education is no exception, and there are periods of high intensity work to meet deadlines throughout the academic year. The key is not to avoid hard work, but to recognise when hard work becomes exhaustion (Wax 2017; 2013). The problem is two-fold. First, there can be cultural norms that reward (with status) those who demonstrate overly-long working hours in higher education (see above about authenticity). Second, it can be very hard to recognise your own exhaustion. Those around you may see changes in your behaviour and mood, but the mind is

adept at obscuring this from oneself. Abject exhaustion in one's work life runs the same risk as a marathon runner 'hitting the wall' at the 22-mile point, one moment you are running and the next you are on the ground unable to move without a clue how you ended up there. This workshop will facilitate participants' explorations of what working in Higher Education means for them, focusing on what authenticity and exhaustion would look like in individual cases. In this way, participation will help individual's devise their own strategies to ensure a healthy balance of wellbeing in their career within Higher Education.

AIM OF WORKSHOP

This workshop aims to provide colleagues with a personal framework for managing wellbeing within their academic career. The workshop is aimed at PhD students and early career academics (both teachers and researchers) who work in Higher Education.

Maximum number of participants - 20

WORKSHOP SCHEDULE

This workshop will involve interactive discussion, small group activities, and individual reflection.

The flexible running order to the workshop is:

- 00 – 15: Ice breaker exercise that also serves as an introduction.
- 15 – 30: Introducing the concepts of authenticity and exhaustion as components of wellbeing.
- 30 – 60: Small group action learning sets to explore individual experiences and perspectives on authenticity and exhaustion.
- 60 – 75: Individual activity – designing individual strategies to enhance wellbeing.
- 75 – 90: Plenary and personal pledges for post-workshop tasks.

WORKSHOP OUTPUTS AND OUTCOMES

Participation in this workshop will provide colleagues at the start of their academic career, with the means by which they are able to develop a bespoke approach to understanding and monitoring their own wellbeing. This will be achieved through the following two outcomes of the workshop:

- 1) Participants will critically reflect on authenticity and exhaustion as factors that can impact on one's wellbeing – identifying these as factors as a component of wellbeing is often seminal in itself.
- 2) Participants will develop their own individual strategies to enhance authenticity and gain resilience to exhaustion – these are intended to be germinal strategies that participants can develop and refine over weeks, months, and years after the workshop.

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Exploring Video for Assessment in Student Assignments

Clarke, Angela, Hagemeyer, Severijn

University of Warwick

angela.clarke@warwick.ac.uk

KEY WORDS: Video Assessment: Student Assignments

SUMMARY

The use of video for assessment, as an alternative to written assignments has been explored in the literature and an overview of the practical considerations of using video assessment was also presented at an earlier paper in the EERN conference (Hagemeyer and Clarke, 2019). Recent literature contains many useful discussions and case studies on this topic (Hawley and Allen, 2018; Armstrong et al, 2018; Beck, 2016, Devereux, 2019), but with relatively few practical examples showing the effectiveness of video for assessment.

In this workshop, an examination will be made of the practical considerations and effectiveness of using video for assessment. As part of the discussion, the main themes to be examined are expected to be:

- An evaluation of the circumstances under which video assessment is considered to be an appropriate tool
- A review and discussion on what makes practical and effective video assessment
- A discussion on what support is needed to help both assessors and learners use video effectively as a tool for assessment.

AIM OF WORKSHOP

This workshop aims to collate and connect existing practice on the topic from the literature and to explore more deeply the practical considerations of using video for assessment. In particular, it will examine a mini-case study from WMG in which the results from the application

of the suggestions presented in Hagemeyer and Clarke's (2019) paper have been collated. It will refer to and use this work to springboard a facilitated discussion and sharing of good (and bad) practices relating to the use of video for assessment. The video for assessment topic will be considered from both the point of view of the assessor/instructor and from the point of view of learners, as their needs are different (OECD, 2013).

The workshop is likely to appeal to instructors and assessors currently using or thinking about using video for assessment, as well as researchers engaged in this topic. The aim of sharing the case study is to promote discussion on the above topics. A maximum of 30 participants can attend.

WORKSHOP SCHEDULE

- Introductions and share 'experiences' of using video – 15 mins
This session will collate the experiences of attendees, and facilitate a discussion on what knowledge is available on the topic. The aim is to provide some context for the remainder of the workshop.
- Review and discuss themes introduced in the presentation made by Severijn Hagemeyer – 15 mins (*it is recommended that workshop participants attend the presentation entitled the Use of Video for Assessment in Student Assignments*)
 - Strengths & weaknesses of video assessment
 - Practical Requirements to ensure effective video assessment
- Share a mini case study of the use of video for assessment in WMG - 20 mins
 - A short presentation of how video assessment was used in practice in a recent WMG module, and review of evidence showing well the video assessment appeared to work, from both a student and instructor perspective.
 - Following the presentation will be a facilitated discussion on how this approach could be improved
- Preparing instructor/assessors for the video assessment – facilitated discussion 15 mins

(based on presentation entitled the Use of Video for Assessment in Student Assignments)

- This session is likely to be a follow on from a previous discussion

- Preparing learners for the video assessment – facilitated discussion 15 mins
(based on presentation entitled the Use of Video for Assessment in Student Assignments)

- Sum up/wrap up – 10 mins
 - This session will highlight actions for workshop attendees to take away, as well as a signposting for further information.

WORKSHOP OUTPUTS AND OUTCOMES

Colleagues will gain a good understanding of the strengths & weaknesses of using video for assessment, an appreciation of where and how video might be most useful in assessment and also they will leave with some tips and signpost on how to use video assessment effectively.

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Using Signature Pedagogy in Curriculum Design: Breaking the Tyranny of Content in a Degree Apprenticeship

Edwina Jones¹ Celine Martin¹ Graeme Knowles¹, Jane Andrews¹

WMG, University of Warwick

Edwina.jones@warwick.ac.uk.

KEY WORDS: Curriculum Design, Signature Pedagogy, Degree Apprenticeship

SUMMARY

Curriculum design has been a knotty problem for educators over the years. This workshop looks at an approach utilised within WMG at the University of Warwick to the re-design of a Degree Apprenticeship programme (the Advanced Engineering Programme). One of the key challenges was to ensure alignment with the AHEP requirements of the Institute of Engineering and Technology and the degree apprenticeship standard for engineering. The approach helped the team to de-focus on the content of the programme and emphasis the key habits of ‘heart’ ‘hand’ and ‘head’ identified by the team as the critical characteristics of WMG Degree Apprentice Engineer.

LITERATURE REVIEW

Curriculum design has been a critical consideration across educational disciplines for many years (e.g. Fung, 2016). Approaches including constructive alignment (Biggs & Tang, 2007), concept mapping (e.g. Toral et al, 2007) and the Connected Engineer (Fung, 2016). In Engineering Education the approach to curriculum design is further complicated by the requirements of accrediting bodies and, in the case of Degree Apprenticeships, by the requirements of apprenticeship standards – developed by so-called ‘Trailblazer’ groups of employers. These additional constraints have led programmes of study to be effectively content led – as Rompelman & de Graaff (2006) note; ‘a curriculum is described on the basis of the contents by

summing up the modules'. This approach creates an input rather than output focused approach, which causes issues with things like cohesiveness of the curriculum and authenticity of the learning experience.

One of the more recent and less utilised approaches is the concept of Signature Pedagogies (Shulman, 2005). This approach considers the fundamentals of how educators prepare students as future practitioners of the discipline; Gurung, Chuck & Haynie (2009) took this approach further to consider the habits of 'Head, Hand and Heart' fostered by pedagogies in disciplines. This evolution is interesting as it goes beyond the Habits of Mind considered by, for example, Lucas and Hanson (2016) who went beyond pedagogies to understand the habits of mind (HoM) most commonly deployed by practising engineers.

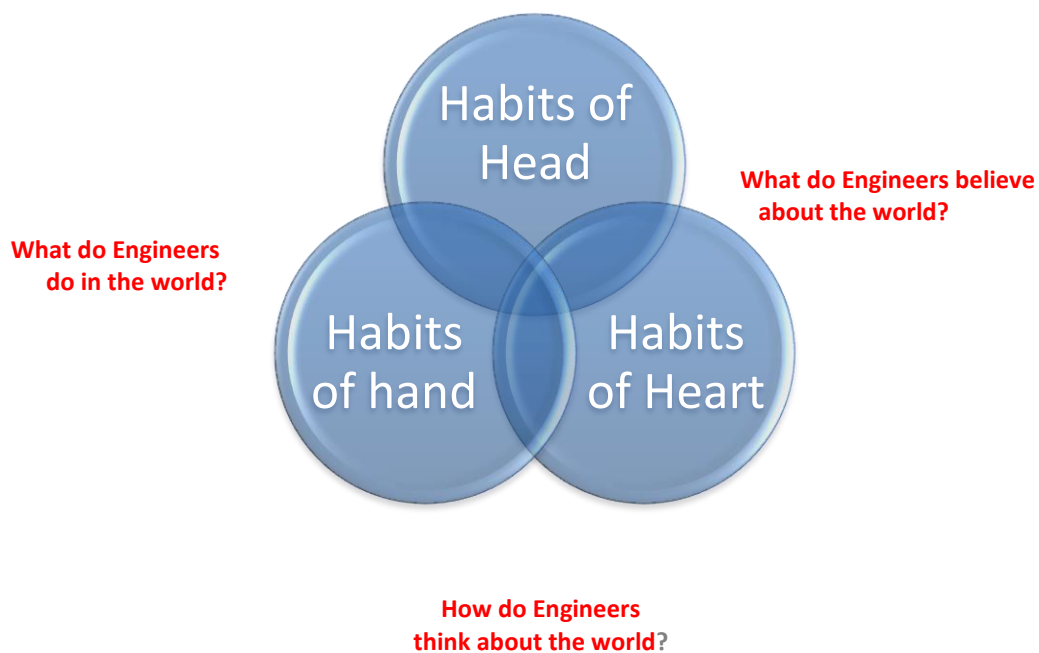


Figure 1. Habits of Head Heart and Hand (informed by Lucas & Hanson, 2016 and Shulman, 2005)

In this work, we have also drawn on the concept of holistic student development (i.e. attention to developing personal, spiritual and character elements of the individual as well as professional and discipline-specific attributes – e.g. Quinlan, 2011). Figure 1 shows a schematic of the thinking applied and it is the application of this to practical curriculum design that we shall explore during the workshop.

AIM OF WORKSHOP

Grounded in the emergent findings of our study, the workshop activity is designed to help colleagues get to grips with the practical design of Engineering Education programmes using signature pedagogies. Using the case of a new open Degree Apprenticeship programme in engineering, the workshop will illustrate how approaches such as Signature Pedagogies and Threshold Concepts can be combined to energise staff around developing a programme which is driven by the vision of the Engineer developed through the programme, and not by the technical content of the programme.

WHO SHOULD PARTICIPATE?

The workshop is aimed at those colleagues who have an interest in the evolution of curriculum design in Engineering Education, particularly in the rapidly emerging area of Degree Apprenticeships. No prior experience is necessary. The workshop provides the opportunity to work with a case study which is currently being implemented within WMG and to reflect upon the process to establish some core principles and practices for their own curriculum design practice.

WORKSHOP FORMAT

The activity will start with a brief introduction to the case and a quick description of the approach followed by an opportunity for colleagues to apply the approach to their own programmes of study.

WORKSHOP SCHEDULE

The workshop will be structured as follows:

1. Introduction to the case and design principles applied (10 minutes)
2. Group Activity: Course in a tweet (10 minutes)
3. Group feedback: Identifying themes and issues (10 minutes)
4. Group Activity: World Café – Habits of Head, Hand and Heart (20 minutes)
5. Group feedback: Identifying themes and issues (10 minutes)
6. Brief presentation of the rest of the approach (10 minutes)
7. Plenary: Building the future – An emergent conceptual approach (20 minutes)

WORKSHOP OUTPUTS AND OUTCOMES

For colleagues the key outputs of the workshop will be:

1. An improved understanding of the way in which a range of pedagogical and design principles can be combined into a coherent approach to curriculum design.
2. The opportunity to feel how the approach works and compare their outputs to those of the team.
3. An opportunity to engage with the research going forward.

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How to Turn your Research into a Living Curriculum

Preston, Anne^a Nyamapfene, Abel^b

University College London

anne.preston@ucl.ac.uk

KEY WORDS: Student-Led Learning, Inclusivity, Participation In Research, Research-Based Teaching

SUMMARY

This workshop is aimed at PhD students and Early Career Researchers with an interest in considering the place and relevance of their research for broader communities of people beyond the immediate engineering sector, including undergraduate and post-graduate students. It is motivated by practice-based research which sought to involve students and community members in more specific ways to the development of international research into engineering education in Egypt (The Hilali Network). This workshop takes a practical and pragmatic approach to supporting an important element of early career development: supporting reflections around inclusivity and participatory approaches in how research is shared and developed. It is based around two key hands-on activities. The first encourages participants to look at issues such as the power dynamics in engineering education projects, including some of the moral implications and ethical issues. The second promotes the integration of participant's research into key areas of a living curriculum to develop design thinking around how research is integrated with and is inspired by the world students and other communities live in.

AIM OF WORKSHOP

Being an early career researcher is not easy. Spinning the many plates of academia starts particularly early in the engineering sciences, as building a career involves working closely with peers and senior colleagues, developing one's professional identity and independence, teaching

and marking, applying for funding, as well as writing a thesis. This workshop takes a practical and pragmatic approach to supporting an important element of early career development which spans a lot of these areas: supporting reflections around inclusivity and participatory approaches in how research is shared and developed beyond the thesis. For example, in a teaching context, how do we move beyond the presentation of our research as a case-study to provide opportunities and inspire our students to learn through participating in research and enquiry?

By the same token, when sharing our research in other contexts what opportunities do we create and embed in our research approaches to sustainably open up our outputs to communities both inside and outside the UK?

Going further, in a recent publication by the Institute of Engineering and Technology and Engineering Professors Council (IET, 2019), there has been particular emphasis on the changing career paths of engineering graduates (on all levels) and a call to address the new generation of potential engineers who want to study and work in different ways. Stand out points in this report include increasing diversity, a greater emphasis on creativity and partnership working and greater interdisciplinarity. In line with these calls, there are many questions such as how we support students' and our own skills in working in interdisciplinary teams, how we broaden our own and our students' practical understanding and ability to embrace diversity.

Emerging concepts are being introduced into higher education programmes to address the development of future-facing engineering education such as those in the Relationship Variety and Synergy model of engineering education (Clark and Andrews, 2014) which support creativity in interdisciplinary designed learning. Elsewhere, there have been new approaches to increase participation by underrepresented groups in engineering and making diversity and inclusivity a core part of the curriculum such as the integrated engineering curriculum for part-time students at The Open University (Morris, et al, 2017).

The success of future endeavours like this, which will be led by the next generation of engineering educators, can be inherently linked to the kinds of starting point early career researchers and PhD students have when considering the place of their own research (and any teaching they do) in relation to their own views and attitudes towards around inclusivity and participatory approaches in how research is shared and developed.

This workshop will provide participants with hands-on experience in using the notion of a living curriculum in thinking about how we configure participation in our research, in order to extend its impact beyond our immediate research (and teaching) context. A living curriculum “repositions learning as a continuous conversation within a dynamic curriculum that is integrated with, and takes advice from, the world our students live in” (Marshall and Wilson, 2012, p. 2).

A particular focus is on the role that undergraduate and post-graduate students can take in supporting new ideas and understandings of the impact of your research. The approach introduced in the workshop can also extend to how we work with other communities, where we seek to encourage greater involvement and representation of community voice and which goes beyond typical outreach activities. This is certainly something that research-councils now support and expect researchers to participate in.

WORKSHOP SCHEDULE

Designed for 25 participants to work in groups of up to 5 people, the workshop will involve two key related activities.

Introduction and Motivations (15 mins)

Face to face introductions to each other

An overview of The Hilali Network, which provides the inspiration for the workshop. The project involved building a living curriculum for STEAM based on participatory approaches involving undergraduate engineering students and community members working on joint projects in computing science and cultural heritage.

Power Dynamics (25 mins)

The purpose of this activity is to encourage students to engage and share some of the moral implications and ethical issues of their research. By the use of one local instance of an

engineering education project (to be decided in each group), participants will be able to easily focus on the variety of stakeholders in such projects, as well as their places in the distribution of power/benefits. Participants will share their findings and discuss them with the other groups.

Building your living curriculum (25 mins)

In this activity, participants will be provided with 5 key working principles of a living curriculum based on the outcomes of the Hilali project: Localisation; Co-creation; Sustainability, Real-world application and Openness. Drawing on these principles, they will be encouraged to work as a group to identify different ways in which they could be used to design activities for students or other communities based on the earlier identified engineering education project. The power dynamics activity provides a backdrop to consider the design of the activities in light of the beneficiaries and power balance previously identified.

Consolidating and sharing (25 mins)

In this activity, participants will be invited to share a selection of their activity designs from the previous activity and encouraged to subsequently submit these for inclusion on The Hilali Toolkit (<https://hilali-toolkit.com/>).

WORKSHOP OUTPUTS AND OUTCOMES

Based on practice-led research carried out in Egypt in the summer of 2017, this workshop will introduce participants to the notion and value of a Living Curriculum for Higher Education.

Benefits for students include them becoming more engaged, responsible and pro-active learners and therefore gaining a stronger sense of belonging to participants' research fields. Benefits to researchers include gaining the expertise and enthusiasm of students motivated to help make positive change. Working with other communities, researchers can learn more about how the impact of their work on communities and develop new ideas for future research-based educational design for future funding and for teaching.

More specifically, participants will, as joint activity:

1. Identify the range of stakeholders involved in the area of engineering education
2. Evaluate the role of stakeholders in the area of engineering education
3. Identify a range of ethical and moral dilemmas associated with engineering education where stakeholders play a role.
4. Identify methods and approaches which can help them design in participatory approaches to involving students and other communities in their research.

It is hoped that participants will see the relevance and applicability of the approach to the development of their own research and research-based teaching.

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Xtended Reality in Engineering Education: Developing a Taxonomy

Graeme Knowles¹, Jane Andrews¹, Robert O'Toole²,
Irwyn Shepherd³ Rajendran Parthiban⁴

WMG, University of Warwick¹; IT Services, University of Warwick²;
e-Solutions Monash University³; Engineering & IT Monash University Malaysia³

g.knowles@warwick.ac.uk

KEY WORDS: Virtual Reality; Engineering; Education; Taxonomy

SUMMARY

From fantastical virtual worlds, to augmented design tools and immersive training environments, immersive technologies are opening doors to new opportunities every day. But for educators, technologists and researchers driving its development, there is a lack a common language to describe the way we identify, create, define, refine and value immersive content. There is also no definitive pedagogical framework underpinning this application of technology and providing a scaffold in ensuring educational and simulation fidelity.

Education today faces serious challenges around the globe that Rizov and Rizova (2015) compare to the challenges of the Industrial Revolution in their significance. A new breed of students who are 'digital natives', immersed in new technologies are entering institutions which have historically been slow (and not always successful) in integrating beneficial new technologies into their learning environments (e.g. Cuban, 1986; Henderson et al, 2017). Critical issues are the 'massification' of higher education indicative of what often seems to be ever-increasing student numbers further complicated by an increased demand for personalisation of both learning and support. At the same time educators find themselves strongly encouraged to introduce active learning and authenticity into the classroom.

The benefits of active learning have long been acknowledged and researched; for example, Benware and Deci (1984) found that active learning had positive impacts on intrinsic motivation, conceptual learning scores, and higher perceptions of active engagement; whilst more recently Cui (2013) demonstrated it enhanced student's cognitive outcomes. Whilst, authenticity in learning has been shown to have positive impacts on student engagement, satisfaction and outcomes, as well as helping to prepare students for future careers more effectively (Sutherland & Markauskaite, 2012; Cavenett, 2017)

One of the critical and well-researched approaches to incorporating personalisation, authenticity and active learning has historically been Simulation. Simulation is a broad-based educational technology which seeks to immerse learners in a realistic representation of the professional world and to leverage the benefits of authentic and active learning. In taking a critical yet holistic perspective, it is reasonable to argue that the use of Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR) and Extended Reality (XR) fit within the broad concept of Simulation; forming part of continually changing, fast-emerging, and potentially even more immersive approach to how learning and teaching is practiced (Senthilvel et al, 2019; Hahn et al 2019). Accordingly, a good working hypothesis is that the principles of the effective use of Simulation will broadly apply to the most appropriate use of XR and other similar immersive technologies.

As a relatively new set of technologies XR has little in the way of experimental research publications to draw on, and much of the pedagogical research in the area lacks a degree of robustness. However, there are indications that it has potential to be beneficial in a number of ways:

- Broadening access to laboratories: Davies (2008) points out the importance of lab practicals in promoting discipline-specific skill sets and is especially valuable in subjects such as engineering. Growing numbers of students make access to expensive laboratory facilities both costly and practically challenging- and XR technologies have the potential to improve this, as well as allowing students to experience situations which would be hazardous in real life. Andujar et al (2011) showed, for example, that AR improved the effectiveness of remote laboratories.

- Personalization of learning: Valdez et al (2015) note that virtual laboratories give students more flexibility in terms of pace, place and ability to re-experience the learning.
- Immersion and engagement with complex ideas: Stansfield et al (2018) showed preliminary results which indicated improvements in learning and engagement for students using AR/VR over traditional learning environments when studying materials testing and photo-voltaic cells.

What is, perhaps lacking for more widespread application of the approaches is a more strategic approach to understanding where and how immersive technologies might be effectively and, equally importantly, cost-effectively, deployed within the educational environment so as to enable engineering educators to better deliver learning and teaching. Indeed, there is a significant gap in knowledge and theory about how to maximise the use of XR as an educational tool. Likewise, a notable gap exists in educational theory about the use of XR from a pedagogical perspective. It is this gap that the research upon which this workshop is grounded is built.

Figure 1 below provides a diagrammatic representation of the study’s initial conceptual framework. Framed by the research question of “How can XR be used to enhance learning and teaching in engineering education” figure 1 outlines the three key variables emerging out of the initial review of literature. Depicted within a Venn diagram so as to show the relational aspect of the variables, the area occupied by all three variables is identified as the ‘sweet spot’.

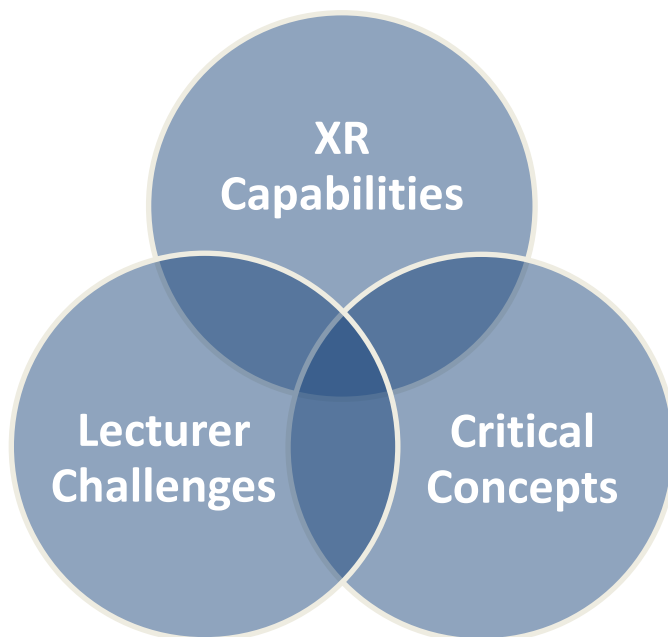


Figure 1: The sweet spot: where XR capabilities and educational needs coincide

Our work thus far has sought to understand what challenges are faced in engineering education at present and to correlate this with the potential of immersive technologies. The main objective at this stage is to develop an understanding of the applications which have most potential to make a difference within an educational setting.

AIM OF WORKSHOP

Grounded in the emergent findings of our study, the workshop activity is designed to help demystify some of the common questions around the creation, delivery and assessment of immersive content. By critiquing and further developing a working taxonomy that describes how best to use such creative formats, it is envisaged that the workshop will improve understanding of the use of immersive content in engineering education. By sharing ideas and experiences we anticipate moving closer to finding the most engaging and sustainable forms of new delivery platforms.

WHO SHOULD PARTICIPATE?

The workshop is aimed at those colleagues who have an interest in the potential of XR technologies to enhance and transform engineering education. No prior knowledge is required as colleagues will be supported throughout. Aimed at providing colleagues with a better understanding of what the term 'Extended Reality' actually means, the workshop will provide colleagues with food for thought about how to maximise the use of 'Extended Reality' in the classroom.

In addition to providing an interesting and interactive activity for colleagues interested in the use of XR technologies in engineering education, the workshop will also be attractive to active engineering education researchers as the workshop findings will be fed into our study data collection; thereby increasing the epistemological and ontological underpinnings of how XR technologies are classified and represented in education.

WORKSHOP FORMAT

The activity will utilise and build upon the interim Taxonomy of XR in Learning & Teaching currently under development. Purposefully being constructed so as to support educators in accessing relevant extant XR learning artefacts and other resources, the taxonomy represents a unique approach to how new technologies may be used to enhance engineering education. Perhaps more importantly, the Taxonomy is being developed with the intention of assisting engineering educators create or expand individual signature pedagogies.

The workshop will commence with a brief introduction to the approach taken by the team thus far. The interim Taxonomy will then be used to form the basis of group discussion about the challenges and benefits of using XR in the classroom. Concurrently, a formal evaluation and extension of the study will take place with colleagues encouraged to play an active part in what is an ongoing engineering education study.

WORKSHOP SCHEDULE

The workshop will be structured as follows:

- A. Introduction to the approach and interim taxonomy (20 minutes)
- B. Group Activity: An opportunity to input into the continued development of the Taxonomy (30 minutes)
- C. Group feedback: Exchange of knowledge and ideas (15 minutes)
- D. Moving Forward: Whole group discussion (15 minutes)
- E. Plenary: Building the future – An emergent conceptual approach (10 minutes)

WORKSHOP OUTPUTS AND OUTCOMES

For colleagues the key outputs of the workshop will be:

- 1) An improved understanding of the potential of XR in Engineering Education.
- 2) Introduction to a tool to help in selecting or developing XR interventions for particular learning and teaching challenges.
- 3) An opportunity to engage with the research going forward and become part of a wider research group in the area.

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Benchmarking Engineering Dissertations

Gratton, Petra^a Gratton, Guy^b

Cranfield University

petra.gratton@brunel.ac.uk

KEY WORDS: Dissertation, Project, Capstone, Supervision

SUMMARY

The engineering dissertation project is an important milestone in the training and education of nascent professional engineers. This workshop will explore what a gold standard of conducting the dissertation project might look like, and through facilitated discussions, give participants the chance to reflect upon and benchmark their institutions' current practice.

AIM OF WORKSHOP

The aim of the workshop is to benchmark current practice in the running of dissertation projects, from the perspective of education leadership, management and supervision, in consideration of their contribution to developing professional engineers. Starting from the experience of participants in the workshop, facilitated discussion will be used to induce a common understanding of various aspects of running the 'major project', and agree amongst participants what identifies a range of quality in practice for a pre-defined list of issues. The output from the workshop may then be used by individuals to self-evaluate their own learning and teaching practice.

The nominal maximum number of participants is 40, but the workshop can be scaled up or down.

BACKGROUND ISSUES

The 'dissertation' is a means of reporting critically on the major (sometimes referred to as capstone) project that is undertaken at the conclusion of a degree course. It is traditionally the most highly weighted assessment element in the award. All candidates for Bachelors and Masters degrees in the UK education system are expected to complete a significant personal project in order to "apply the methods and techniques that they have learned to review, consolidate, extend and apply their knowledge" (QAA, 2014). Similarly, project work, as part of an engineering degree, is expected as a way of delivering a number of learning outcomes concurrently (ECUK, 2014, p10).

The dissertation project contributes to engineering education as an exercise representing, or replicating, possible activities of an engineering workplace, thus preparing candidates for future employment. It tests "hard" (technical) skills as well as "soft" (professional) skills (Gattie et al, 2011; Uziak, 2015), both of which, it is argued, are required to achieve success. Some students appreciate this, and anecdotes, as well as evidence (Cachia et al, 2018) (albeit from a Psychology Department) exist of students balancing opportunities to develop those skills valued by employers against working for the grades they anticipate will 'open doors' to employment. One of the most important of these life-skills is about dealing with uncertainty (ECUK, 2014).

The dissertation project also provides an opportunity to collaborate with industry and other stakeholders, through working with a 'project client' on industry-based projects (Uziak, 2015), thus students can be introduced to prospective employers and improve their employability. Care is needed in managing the expectations of all parties: student, supervisor and client, especially with regard to timeframe (Abdullah et al, 2012). It helps if there is congruence between research interests of all parties.

In general terms, whatever is considered in either undertaking or organising the individual dissertation project may also be applied to the group project, where there is the added complexity for the student of working with a team of peers engaged in similar work. Whilst much guidance exists for writing up projects (e.g. Van Emden and Becker, 2018), and even conducting projects in specific fields (e.g. Naoum, 2012), there is very little guidance about exploiting the engineering dissertation project for career development. *Achieving Success with*

the Engineering Dissertation (Gratton and Gratton, 2020) addresses this and acknowledges the wide variety of engineering projects, including those inspired by industry.

WORKSHOP SCHEDULE

The workshop will commence with a brief introduction of what the authors believe (Gratton and Gratton, 2020) to be important in the dissertation project to the formation of engineers. Our approach encourages students to strive for success, defining *success* in terms of personal, professional and career development, as evidenced by outputs, such as having more confidence in dealing with uncertainty, building professional skillsets and gaining a desired post-graduation job. (maximum of 10 minutes)

The participants will then be divided into several teams, and set the challenge to identify within their teams (in 30 minutes) what a gold standard of engineering dissertation project might look like, through addressing a number of issues, including:

1. Preparing students
2. Matching projects, students, supervisors and project clients
3. Commencing the dissertation project
4. Conducting and reporting
5. Assessment
6. Helping bridge to the future.

The teams will then be invited to provide feedback on their discussions by systematically addressing each of the issues (30 minutes in total). This will be followed by a short summary (10 minutes maximum), and an invitation to the audience to attest their current practice (10 minutes).

WORKSHOP OUTPUTS AND OUTCOMES

The outcomes of this workshop will be a list of identified best practices for dissertation project organisation compiled amongst the participants, which will permit each participant to score their own, or institutional, experience against the benchmark, thus permitting them to identify where there are possible areas for improvement.

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The Art of Literature Studies & Reviews

Saunders-Smiths, Gillian

Delft University of Technology, Delft, The Netherlands

G.N.Saunders@tudelft.nl

KEY WORDS: Literature Review, Types of Literature Reviews, Literature Reviews in Engineering Education

SUMMARY

Literature studies and literature reviews are a form of descriptive research. According to Creswell (2009) a literature review serves several purposes: Firstly, it informs the reader of the review of other similar, or closely related studies that have already been undertaken. Secondly, it frames the importance and relevance of the intended research. Next to that, it relates the intended research to the ongoing developments in the field and finally, it can provide cases for benchmarking the findings of the research.

In many books on research methodologies, this phase is often not even formally mentioned as a study but referred to as information gathering stage (Field & Hole, 2003; van der Gaast et al., 2019 amongst others) with the focus on how to find and organise the information. Thiel (2014) does actually offer a clear description on types of literature and how to value them and somewhat of a systematic approach on how to select literature for inclusion in a review but rarely is the literature review treated as an important phase of research with its own research questions in most current books on research methods.

It is the author's view that as a result of this portrayal of literature studies, many students still employ either a rather haphazard approach of finding literature or rely heavily on the literature recommended to them by their supervisor. Although these approaches are valid and have been employed for many decades (if not centuries) they are not always effective and researchers run the risk of missing relevant papers they were unaware of. The current age of data availability

opens the possibility to employ more structured approaches to carrying out a Literature Review. A currently much observed approach is that of the Systematic Literature Review as detailed in Pettigrew and Robert (2006). However, Booth and Andrews (2009) published a typology of literature reviews for Health in which they list an impressive 14 types of reviews, each with their own pros and cons.

This workshop will introduce the attendees to a more structured way in approaching a literature review in engineering education research. Although graduate students are already well-versed in finding resources and referencing them appropriately, their thesis project is the first time that they are actually required to study literature in detail and identify what the current state-of-the art is in the relevant literature and also where opportunities lie for further development of the body of knowledge.

This workshop will introduce participants to each of these 14 ways and illustrate each with a relevant education-based example. Next, based on actual research questions, (either their own or those provided by the facilitator) participants can debate and choose a method they feel is suitable to find an answer to the research question.

Participants are welcome to bring their own, already formulated, research questions for their literature review to use in the workshop but this is not a requirement. Advance reading of the article by Booth and Andrews (2009) is not necessary, but some may find it useful to avoid an information overload in the workshop.

AIM OF WORKSHOP

This workshop is aimed at young researchers and anyone else who is interested in learning more about the different types of literature reviews that are available to you as a researcher. Based on the article of Grant and Booth (2009) on the typology of reviews, participants will be interactively introduced to 14 different types of reviews and what each type of review is suitable for, illustrated with a relevant example from education research practice where possible.

After that participants can volunteer any of their own research questions and debate in small groups on which type of literature review, they feel is most suitable for their research question.

At the end of the workshop the outcome is reported back to the plenary session. At the end of the workshop, time allowing, a short discussion will take place on the merit of writing a similar article to that of Grant and Booth (2009) in the field of engineering education research.

The capacity of this workshop is 30-40 people allowing for 5-6 discussion groups

WORKSHOP SCHEDULE

- 0.00h Introduction and creation of groups round table
- 0.10h Literature Study & Reviews: What are they? Why do they exist? Which types do you know?
- 0.20h Introduction to the 14 types of literature reviews
- 0.40h Explanation of exercise and selection of volunteers and research questions?
- 0.50h Discussion in small groups on suitable review type for chosen research questions
- 1.10h Feedback to plenary per group
- 1.25h Closing and Steps forward on Literature Reviews in Engineering Education Research

WORKSHOP OUTPUTS AND OUTCOMES

At the end of the workshop colleagues will come away with a more detailed overview of possibilities of literature reviews and which type of review is suitable for what type of research and be inspired to make a more method-based choice when they next carry out a literature study or review.

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