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Bridging the Gap Between Engineering Workforce Needs and Student Engagement

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Bridging the Gap between Engineering Workforce Needs and Student Engagement

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Abstract[58]

This paper is inspired by the development of the proposed new technological university in Dublin; TU4Dublin is to become "Dublin's Globally Engaged University" and is to be located at the nexus between learning and engagement (TU4Dublin, 2015). This study investigates engineering education in the context of career focused education. The main objective of this study is to investigate whether engineering students' cognitive engagement benefits from bridging the gap between technical issues and the practical realities of modern engineering practice. A portfolio of engineering practice illustrating the practical realities of modern engineering practice in the context of Engineers Ireland's competencies is developed and presented to first year electronic engineering students at the Institute of Technology Tallaght Dublin (ITTD). A mixed methods approach is used to evaluate the impact of the portfolio usage on first year electronic engineering students' learning engagement. The results show that heightened interest in professional practice increases students' value of engineering education and consequently students demonstrate greater cognitive engagement. It is concluded that incorporating real life engineering experiences into the first year engineering education experience greatly enhances it.

Keywords: students' cognitive engagement*,* engineering practice, social cognitive expectancy-value theory

Professional Formation of Engineers includes both formal and informal processes and value systems of becoming an engineer. Modern engineering practice includes "complex social, physical, and information interconnections" (Sheppard, Macatangay, Colby, & Sullivan, 2009). However the technical and mathematical sciences on which engineering courses are built often do not explain the landscape of practice (Trevelyan, 2013) and first year engineering students in particular do not see the big picture surrounding technically focused courses and how they relate to "real" engineering (National Science Foundation, 2014). Additionally there are misconceptions as to what engineers actually do (Anderson, Courter, McGlamery, Nathans-Kelly, & Nicometo, 2010; Cunningham, Lachapelle, & Lindgren-Streicher, 2005; Tilli & Trevelyan, 2008).

It is asserted that a lack of understanding about engineering limits the number of students entering and persisting in engineering education (Courter & Anderson, 2009). In addition to enabling students to manage the transition into commercial engineering contexts more easily, it is proposed that a portfolio of engineering practice will enable educators to design learning experiences that increase students' interest in engineering. According to social cognitive expectancy-value theory engineering students with heightened interest in professional practice will demonstrate more cognitive engagement (Schunk, Pintrich, & Meece, 2010; Wigfield & Eccles, 2000;

Wigfield & Eccles, 2002). Additionally increased knowledge of occupations is associated with greater confidence in career choice (Lent, Brown, & Hackett, 2002).

Social Cognitive Expectancy-Value Theory

Wigfield and Eccles' social cognitive expectancy-value model of achievement motivation posits that predictors of achievement behaviour are: expectancy (am I able to do the task?); value (why should I do the task?); students' goals and schemas (short- and long-term goals and individuals' beliefs and self-concepts about themselves); and affective memories (previous affective experiences with this type of activity or task) (Schunk, et al., 2010; Wigfield & Eccles, 2002). Students enter tasks with different personal qualities, prior experiences and social support which influence their initial sense of self-efficacy for learning. Expectancy-value research has substantiated that students with positive self-perceptions of their competence and positive expectancies of success are more likely to perform better, learn more and engage in an adaptive manner on academic tasks by exerting more effort, persisting longer and demonstrating more cognitive engagement. Students who value and are interested in academic tasks are more likely to choose similar tasks in the future. Interest refers to the liking and wilful engagement in an activity (Schunk, et al., 2010; Wigfield, 1994; Wigfield & Eccles, 2000; Wigfield & Eccles, 2002). Students' goals and self-schemas as well as affective memories predict student achievement. Goal setting is a key motivational process and learners with a goal and a sense of self-efficacy for attaining engage in activities they believe will lead to attainment (Schunk, et al., 2010).

Methodology

Portfolio of Engineering Practice

The portfolio of engineering practice, developed for this study, presents four different perspectives of engineering practice: (i) what exactly do engineers do (Trevelyan, 2014), (ii) education standards required for professional titles of Chartered Engineer set out by Engineers Ireland, the professional body representing engineers in Ireland (Engineers Ireland, 2014), (iii) industry examples of programme outputs that comprise Engineers Ireland education standards and (iv) real engineers stories about their work in engineering practice.

What exactly do engineers do? This section describes the landscape of practice as described by James Trevelyan (2014) who uniquely sets out what engineers do and how they do it. The overarching theme is that while many issues in engineering practice are perceived as "non-technical", in the world of engineering, it is shown that these are thoroughly technical. In essence engineering is human performance and not engineering products. While there are various engineering disciplines, roles and companies, it is the technical expertise that distinguishes engineers as an occupational group. Engineers provide value e.g. economic value, social justice, sustainability, safety, protecting the environment, security, defence etc. Socio-technical factors

shape the landscape of practice; however it is the technical issues that frame communication and collaboration (Trevelyan, 2014).

Myths that engineers are naturally concise and logical are dispelled; in fact many engineers struggle to express themselves concisely and logically. Instead of solving problems, expert engineers know how to avoid problems. Research shows that social interactions and communications take up much more time than solitary technical work such as designing and problem solving. Social interaction provides access to the necessary expertise for expediting solutions. A significant challenge in engineering practice is interpreting client requirements and complying with standards, regulations, social needs and environmental constraints. At the same time engineers have to work with missing and uncertain information. There is never enough time to investigate everything; engineers rely on precedent, their ability to learn from others and computer tools such as spreadsheets to do the mathematics. In summary engineers need to know it all: the engineering enterprise, explicit knowledge, procedural knowledge, implicit knowledge, tacit knowledge, contextual knowledge, engineering knowledge and technical knowledge in the workplace (Trevelyan, 2014).

What education standards do professional engineers require? Engineers Ireland specifies that engineering education should ensure that graduates demonstrate minimum achievement in seven programme outcomes (Engineers Ireland, 2014), these are listed in Table 1.

Are there real engineering examples? EirGrid plc, the independent electricity transmission system operator in Ireland and the market operator in the wholesale electricity trading system (Eirgrid plc, 2014), provides real engineering examples of Engineers Ireland programme outcomes. Some examples are illustrated in Figure 1.

What do real engineers do? The portfolio contains the stories of twenty professional engineers practising in Ireland. These are engineers' individual stories about their engineering education experiences, their career decisions and their work in engineering practice. The stories were compiled following interviews with a sample of 20 professional engineers (Goold & Devitt, 2012a). A snapshot of two engineers' stories is illustrated in Figure 2.

Study Population

The population of interest is first year full-time electronic engineering students at the Institute of Technology Tallaght Dublin (ITTD). Of the 35 first year full-time electronic engineering students at ITTD, 12 students participated in this study. The group consists of only one female student and comprises a diversity of student ages.

Study Design

The mixed methods approach comprises surveys, with both quantitative and qualitative questions, that capture first year electronic engineering students' perceived value of their engineering education and their

feelings about their future careers before and after their portfolio experience. The survey questions are included in Table 1.

The quantitative questions employ a Likert scale with 5 points (1 = Not at all; 2 = Very little; 3 = A little; 4 = Quite a lot; and 5 = A very great deal). Population means with 95% probability are calculated and a paired t-test is used to determine if there is a difference (with 95% confidence) between the perceived importance of Engineers Ireland programme outcomes before and after the portfolio (Reilly, 2006). The qualitative questions are analysed using a system of open coding (Miles & Huberman, 1994; Silverman, 2010). This involves grouping together sections of survey responses that share some common meaning for both survey responses. The findings result from the subsequent emergence of distinctive themes from the coded data. Students' comments are also recorded.

Figure 1 Examples of engineering practice aligned to Engineers Ireland programme outputs

Results

The quantitative results are presented in Table 1. While students generally "enjoyed" their first semester of engineering education, it was also a "*totally new experience.*" Students are on average very interested (Likert mean value 4.333) in working as an engineer; reasons given include job prospects, general interest in area and interest in "*building stuff.*" Students' value of their engineering course relates only to jobs e.g. "*jobs are hard to get*

and a degree is a minimum requirement." While students highly rate the usefulness (mean = 4.250) of their course for preparation for work as an engineer, the reasons given are vague, e.g. "*it's a little too early to tell what the full skill set will be but I am presuming that we will be given very good building blocks to start with.*" Students' beliefs about engineer's work include building, fixing and designing; examples include "*make sure things work,*" "*fix, diagnose and see solutions to various aspects of electronics*," "*building things,*" "*design/build PCBs,*" "*make machines work,*" "*design components, design circuits*" and "*debugging and maintenance.*" Students' examples of real-world practicality skills are based on their engineering education thus far, these include "*soldering,*" "*reading printed circuit boards*," "*build digital timer circuit,*" "*aspects of learning to learn*" and "*maths obviously has to play a big role in the real-world aspect.*"

Current work: Engineer C is the department manager of the mechanical engineering group in an Irish founded multi-disciplinary engineering firm that develops solutions for complex capital projects serving multinational clients worldwide. As well as managing twenty eight engineers, Engineer C also works as a lead engineer on many projects.

Engineer C's job does not "require a huge level of maths but invariably something will come along" that requires a mathematical approach. He contrasts school mathematics where "there must be one answer" with his current job whereby if he came "to one solution ... that would be a disaster"; instead he must look at how his "design fits in" with the other disciplines. Engineer C has "set up the computer to do all of the maths". In Engineer C's work "thinking is everything" and his clients require him to "think about the alternatives". Engineer C states that being "in the right train of mind" gives him a "certain amount of fulfilment".

Current work: Engineer U works with a major Telecommunications Company where he manages a team of ten engineers who "design" the transmission network.

Engineer U requires "a mathematical view" in "everything" he does at work. His company is "riddled" with "black box software solutions". When designing networks or solving "synchronisation" problems, he needs to convert "things like man hours into megabits per second" and create documents for the "finance people to provide" the money. These documents have to be "double" checked and while mathematically based they have to be put into "a form that a non-engineer will understand". When managing the "capacity in the network", he has to make decisions "based on problem solving and logical thinking". He has to do a "certain amount of estimation" to predict future network usage, for this he relies on both his "experience" and knowledge of "statistics". As his career progresses he is "doing a lot more management orientated as opposed to problem solving oriented or design orientated" tasks and he has "to apply the maths" not just to engineering but to all the aspects of his company".

Engineer C	Male	Age 30 - 40	Project Engineering
Mechanical	Design/Development role	Maths usage 1.76/5	

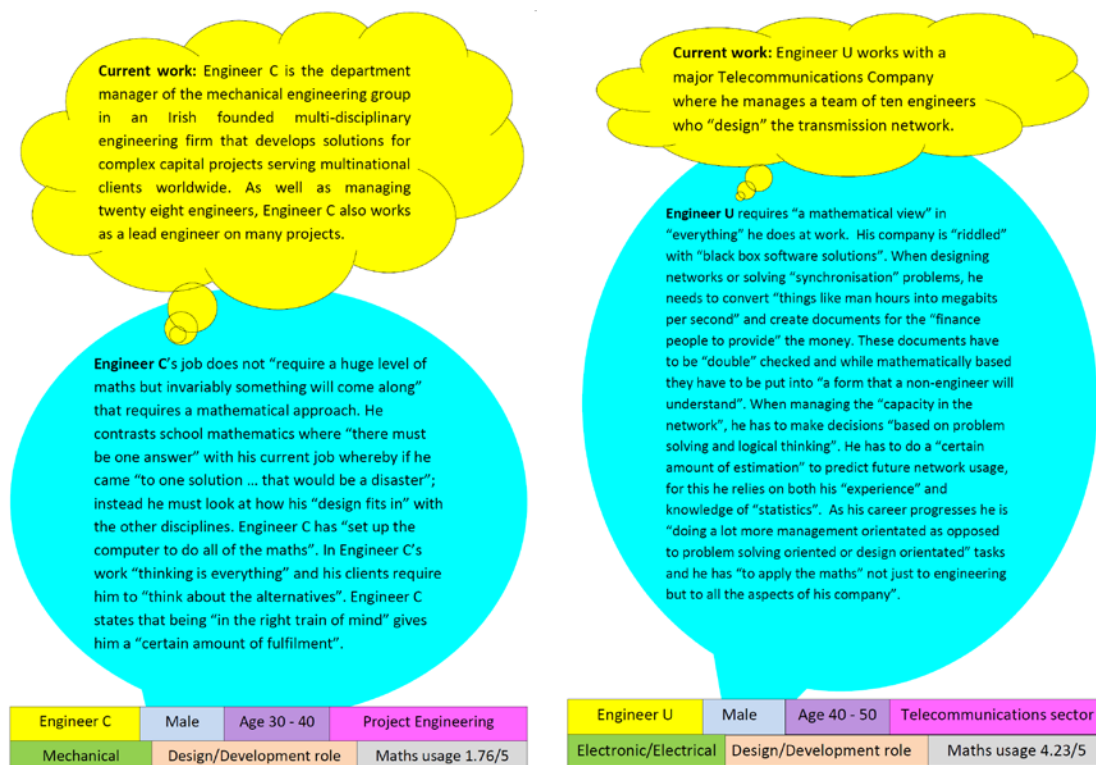| Engineer U	Male	Age 40 - 50	Telecommunications sector
Electronic/Electrical	Design/Development role	Maths usage 4.23/5	

Figure 2 Engineers' stories about their professional work

Examples of course content students think would inspire deeper learning engagement also focuses on the practical aspects of engineering education, these include "*electrical circuits,*" "*robotics,*" "*hands-on practical stuff*" and "*more about the components, equipment etc.*" Student also see value in incorporating "*internship,*" "*the actual expectation in a work environment*" and "*a project to make a simple circuit to replace a circuit that exists in a real product*" into their learning. Students' examples of Engineers Ireland programme outcomes are sparse; however students do have strong beliefs about mathematics, "*in practice maths is required in everything.*"

Table 1 Results

Before the Portfolio			
QUESTIONS	**Mean**		
1. Briefly describe your first semester electronic engineering experience, include your feelings (enjoyment, interest etc.) about the course			
2. How interested are you in working as an engineer? **Why?**	4.333		
3. How valuable is your engineering course to you? **Why?**	4.333		
4. How useful is your course for preparation for work as an engineer? **Why?**	4.250		
5. Is there anything specific you would like to have included in the remainder of your course? **Why?**			
6. What do you think electronic engineers actually do at work? **Give examples**			
7. Does your course teach you real-world engineering practicality skills? **Give examples**	4.000		
8. Can you give examples of course content you think would inspire your deeper learning engagement/ interest in your course? **Give Examples**			
9. **Engineers Ireland Programme Outcomes**	**Before Portfolio**	**After Portfolio**	**P value**
A. Advanced knowledge and understanding of the mathematics, sciences, engineering sciences and technologies underpinning electronic engineering	4.667	3.917	0.002
B. The ability to identify, formulate, analyse and solve complex engineering problems	4.250	4.500	0.491
C. The ability to perform detailed design of a novel system, component or process using analysis and interpretation of relevant data	4.417	4.083	0.266
D. The ability to design and conduct experiments and to apply a range of standard and specialised research tools and techniques of enquiry	4.333	4.333	1.000
E. An understanding of the need for high ethical standards in the practice of engineering, including the responsibilities of the engineering profession towards people and the environment.	4.167	4.583	0.175
F. The ability to work effectively as an individual, in teams and in multidisciplinary settings, together with the capacity to undertake lifelong learning	4.333	4.750	0.137
G. The ability to communicate effectively on complex engineering activities with the engineering community and with society at large	4.417	4.667	0.491
After the Portfolio	**Mean**		
1. Did you like the Professional Practice ("Portfolio") exercise? **Why/ why not?**	3.833		
2. **What** did you learn from the "Portfolio"?			
3. Will the "Portfolio" impact on **your approach to learning** and engagement with the remainder of your course? **In what way?**	3.417		
4. Having completed the "Portfolio", can you identify areas that are neglected / or require greater emphasis in engineering education? **Why?**			
5. Having completed the "Portfolio", do you think that engineering education should put more emphasis on engineering practice in first year?	4.167		
6. Do you think that projects like this improve students' value of their education? **Why**	4.167		

Students note the value of the portfolio; it is described as "*a better insight into engineering,*" "*informing, but way too long,*" "*interesting,*" "*insight from actual sources about what exactly goes on in the engineering industry,*" "*it was very reassuring*" and "*it told us a lot about the actual careers of engineers and was helpful in understanding what to expect in industry.*" Benefits of the portfolio include "*I think it was an eye opener on engineering, what to expect and what to prepare yourself for,*" "*it gave me a great insight into what engineering fields my skills could be applied and what an engineers' job is*" and "*what different types of engineers do and points to help me with interviews.*" Students learnt that "*common sense is important,*" "*a lot of what an engineer can do and how to do it,*" "*duties of an engineer, types of companies an engineer can work for.*" "*The survey with past and present engineers was particularly helpful,*" "*there isn't ever just one way to solve a problem, but many ways.*"

The value of the portfolio is reflected in students future learning aspirations: "*I have a broader understanding of the path I'm taking,*" "*I will start to focus on what I am learning and consider how I would use it in the workplace,*" "*I would probably focus more on organisation and communication skills in the future because they were outlined as important,*" "*I will probably think back to this when covering specific topics in class,*" "*I know now where I could be heading and I know the process of getting there,*" "*I feel the portfolio will help me to think outside the box, I should also be looking at things we are not covering in college*" and "*I have a better knowledge of engineers' work and the skills I learn in college can be applied to work in multiple ways.*" Students increased value of engineering is also apparent, "*I learnt how big and important engineering is.*"

A comparison of the importance of Engineers Ireland programme outcomes before and after the portfolio shows that only programme outcome A (Advanced knowledge and understanding of the mathematics, sciences, engineering sciences and technologies underpinning electronic engineering) changes significantly as a evidenced by p-value of 0.002, Table 1. Prior to the portfolio students' high value of mathematics was apparent, this has reduced after the portfolio, because "*mathematics isn't a vital factor for engineering though important but not necessarily needed to solve all problems*" and "*I learned that the technical side of engineering i.e. mathematics did not dominate the daily lives of engineers.*"

Students say that engineering education should put more emphasis on engineering practice in first year (mean = 4.167). Reasons include "*better understanding of the career you are taking,*" "*let the students know what to expect,*" "*understanding of the engineering workplace could inspire students to do well,*" "*this would help students really know if they want to pursue engineering*" and "*before the portfolio I didn't really know exactly what engineering is and how my skills would apply later on.*" Students also believe that projects like this improve students' value of their education (mean = 4.167) because it "*builds responsibility,*" "*gives us insight of what we will become in the future,*" "*helps focus on what is needed / expected in workspace,*" "*students feel as if they're just here to learn day to day, instead*

they are here to prepare themselves for their future employment, this project could make them realise that," "*students would be inspired to put more effort in to obtain job in industry with prior knowledge of how the industries work,*" "*helps the students target how they are going to study their subjects,*" "*projects like this really help students understand how essential their education is and how important education is outside their course*" and "*I have a greater respect now for what is being taught and will not take it for granted.*"

Concluding Discussion

The impact of the portfolio on students' learning engagement is very evident in this study. For many first year students engineering is a totally new experience; students' values and beliefs about engineering are based solely on their coursework and on the academic viewpoint. While first year engineering students' ultimate goal is to get a job in engineering practice, they have no clear picture of what engineers actually do. This corresponds with the research literature wherein engineering is described as a diffuse professional field because students have "unclear expectations about their transition from study to working life" (Goold, to be published 2015; Reid & Petocz, 2013).

The portfolio positively influences students' expectancy, value, goals and schemas and affective memories which in turn students say will improve their learning and engagement with their studies (Wigfield & Eccles, 2002). There is evidence of increased expectancy for success in future careers: "*I have a better knowledge of engineers' work and the skills I learn in college can be applied to work in multiple ways.*" The study illustrates the value the portfolio creates for students: "*I know now where I could be heading and I know the process of getting there.*" New goals include: "*students would be inspired to put more effort in to obtain job in industry with prior knowledge of how the industries work.*" Some myths about engineering practice are dispelled: "*I think it was an eye opener on engineering, what to expect and what to prepare yourself for.*" Furthermore "*I learnt how big and important engineering is.*" The portfolio is also a source of affective memories; students use personal and positive words to describe their resultant feelings about the portfolio, examples include "*reassuring,*" "*helpful*" and "*points to help me.*"

Students' reduced value of mathematics is interpreted as a positive outcome; it is presented that an awareness of the usefulness of mathematics in students' future careers has greater value than learning mathematics solely for the purpose of passing examinations (Goold, 2014). Similarly investigating engineering practice is valuable for mathematics learning as students show improved relationships with mathematics (Goold, 2015). Furthermore the focus on "objective" solutions in school mathematics at the expense of tacit knowledge has implications not just for engineering education but also for engineering career choice (Goold & Devitt, 2012b).

This study contributes to the knowledge about students transitioning form second level to third level engineering education. Engineering students' reaction to their first semester or year is crucial to subsequent performance (Heywood, 2005). First year engineering students are often confronted with an overcrowded curriculum that is of limited use in graduate engineers'

professional life (Goold & Devitt, 2012b). It is concluded that there is a need to make professional engineering clearer at the outset; the mismatch between engineering education and practice could be reduced by incorporating real life engineering experiences into the first year engineering education experience. It is anticipated that other academic disciplines would also benefit from this type of learning: "*I know now where I could be heading and I know the process of getting there.*"

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