Engaging with Industry to Improve Student Learning on Undergraduate Engineering Programmes

Margaret Morgan
Ulster University

Pearse O'Gorman
Ulster University

Despite the many opportunities offered in engineering programmes for active student participation, a significant proportion of undergraduate students fail to complete their studies. This paper describes how faculty staff have implemented an active participation approach in a second year module in industrial engineering through a series of industrial student visits. Students' participation during the visits and their perceptions of industry before and after the visits are described. Practical suggestions on how site visits to manufacturing companies might be incorporated into the undergraduate engineering curriculum are provided.

INTRODUCTION

A thriving engineering sector is vitally important for the long term success of the UK's economy. Almost one in every five jobs is based in the engineering sector and this sector contributes just over one quarter of the UK's GDP (Dowling and Brinded, 2017). The demand for engineering graduates in the UK already outstrips the supply from UK universities (Skills shortage, 2015). Following the UK's 2016 referendum vote to leave the European Union, it is anticipated that UK universities will struggle to produce enough high caliber graduate engineers with the right technical and professional skills to fill the current and anticipated skills gap in both large and small-to-medium sized, (SMEs), engineering enterprises. Despite recent modest rises in the number of students seeking admission to universities to study engineering programmes (UCAS, 2017), the discipline suffers from higher-than-average levels of programme drop-outs and associated failure rates (Non-continuation rates, 2017).

A study of graduate recruiters in 2008 reported that 80% of firms ranked communication skills, team-working skills, integrity, intellectual ability and self-confidence as the five most important generic skills and capabilities sought by employers generally (Archer and Davison, 2008). Employability attributes specific to engineering graduates identified some six areas that were crucial for employment. These were: application of theoretical knowledge to real industrial problems, theoretical understanding, creativity and innovation, team-working, technical breadth and business skills (King, 2007). Curriculum developers for engineering programmes are faced with the practical difficulties of how they provide opportunities for students to develop the professional soft skills and business awareness that employers have identified as being essential for graduate employment within already packed engineering curricula (Wakeham, 2016).

Unfortunately many engineering students, whilst fully engaged with the mathematical and scientific aspects of their courses, fail to grasp the importance of adequately developing their soft skills and the commercial context of the engineering enterprise whilst at university. There is much debate about how curriculum developers in the engineering disciplines can adopt and use the pedagogic principles underpinning 'active learning' so that all students can actively participate in their studies, fully engage with their programmes' activities and capitalize on all the developmental opportunities that a university education typically offers.

As a regional university, Ulster has well developed links with regional employers, the vast majority of which (almost 99%) are SMEs (Varney, 2008). Most SMEs do not have the resources to employ graduate engineers who work exclusively as technical specialists but rather they are looking to these engineers to provide business leadership, direction and commercial success in technical environments often with very little, if any, in-house training in business management practices. This means that the graduate needs to be 'work ready' and that his/her first degree needs to have provided him/her with sufficient underpinning to enable them to undertake this role successfully (Morgan and O'Gorman, 2010). The graduate employment rates for graduates from the programmes offered in the School of Engineering at Ulster are excellent with 95% in graduate employment within six months of graduation (Unistats, 2016).

As is the case for most other Higher Education institutions offering engineering programmes, engineering courses at Ulster are designed with a number of stakeholders in mind, namely the University, the employers, the professional bodies and the students. Ulster University requires that all its graduates possess the following four graduate qualities:

- subject-specific knowledge and skills informed by current research and professional/vocational practice;
- flexibility, creativity and an entrepreneurial approach to the resolution of problems;
- self-confidence, global citizenship, appreciation of sustainability matters, ethical leadership, and a commitment to life-wide learning, professionalism and employability and
- effective collaborative working, communication skills and the capacity for reflective practice, including the ability to give and receive feedback.

Professional bodies, such as the Institution of Engineering and Technology (IET) and the Institution of Mechanical Engineers (IMechE), accredit engineering programmes against the revised Accreditation of Higher Education Programmes guidelines developed by the UK Engineering Council (AHEP3, 2016) which outlines the UK standard for professional engineering competence: descriptors for each level of accreditation and the associated expected competence level are provided with respect to: Science and mathematics; Engineering analysis; Design; Economic, legal, social, ethical and environmental context; Engineering practice; and Additional general skills.

As tuition fees continue to rise in the UK, students are increasingly weighing up the costs verses benefits of graduating with a university degree. Substantial debts can be accumulated by students whilst they study, and so prospective students are encouraged to make informed decisions about which course and which university is most likely to satisfy their career aspirations and personal development goals. The National Student Survey, first introduced in 2005 for all students in the final year of their studies in Higher Education Institutions in the UK, and the Key Information Sets (KIS) introduced in 2012, means that UK universities are faced with a scenario where data relating to how students actually feel about their courses is in the public domain and is influencing university league table positions and programme choices of prospective students.

METHODOLOGY

In 2012, Engineering programme developers at Ulster, reorganized the first year programme provision so that all programmes within the School of Engineering studied a so-called 'enabler' module, 'Professional Studies'. The aim of this module was to help the student 'learn how to learn at University' and how to actively participate in their studies. Formal lectures on team-work, leadership, conflict-

resolution, oral and written communication were provided in the module and an all-encompassing 'design, build and test' project was set where the assessment of students focused on their grasp and ability to demonstrate the taught principles of active participation.

As part of the course team's approach to incremental and continuous programme improvement, a study was carried out on second year students taking a Design and Industry module on a range of engineering and technology programmes at Ulster University. This module was taken by almost two thirds of the total year 2 cohort in the School of Engineering, and comprised 146 students. The rationale for the module was as follows:

> *The engineer is required to apply good conceptual and detail design if new innovative products are to be developed. An understanding of manufacturing methods and processes, and their implication on design is essential if cost effective products are to be realised. This module further develops engineering design capability and introduces students to real industrial environments.*

The aims of the module were twofold: firstly, to provide students with the opportunity to create, analyse, detail and present designs both in terms of technical and non-technical aspects and secondly to observe and analyse the manufacture of existing products and apply current manufacturing methods and techniques to the design of new products.

The teaching team organized the class into teams of six students for the 'design' part of the module. Students were assigned to design teams by the tutors and teams were comprised from a mixture of programme groups in as far as possible. Previous experience, described elsewhere (O'Gorman and Morgan, 2016) identified that students, in general, preferred to be assigned to design groups rather than self-selecting their own group. Students were required to self-manage their teams and to peer assess their team members contribution and achievement in the group design task - a practical example of collaborative learning (Cusea, 1992).

The 'Industry' part of the module was novel and challenging for the teaching team to deliver, in that, the range of manufacturing processes available within the University was necessarily limited due to resource and space constraints. The teaching team were also keen to get industry more actively involved in the delivery of this module so that students' awareness of the broad range of employment opportunities within the industrial engineering discipline would be increased. Tutors were also keen to introduce an active learning approach whereby students would actively participate on industrial visits and then reflect on their experience and learning – 'do meaningful learning activities and think about what they are doing' (Prince, 2004). It was decided that a series of industrial visits would be provided for students to facilitate them in experiencing the actual workplace and to observe and study the manufacturing processes employed by the business.

A study was designed to elicit students' perceptions of industry before and after the visits, and to gauge if those perceptions had been either positively or negatively affected by the visits. Tutors wished to establish if our students recognized the "value" of the industrial visits as an integral part of their respective programmes. A questionnaire comprised of a series of both closed and open-ended, free response questions was administered to all students at the end of the module. The questionnaire invited students to reflect on the benefits of their visits and to provide course teams with practical suggestions about how site visits to manufacturing companies might be successfully incorporated into the undergraduate engineering curriculum in the future.

The teaching team divided up the student cohort into seven groups for the industrial visits. Nine manufacturing companies in both the electrical/electronic and mechanical/industrial engineering sectors were contacted to ask if they would host a technical visit by engineering students. The large engineering companies selected were: Montupet UK, Ryobi, Bombardier Aerospace, and the smaller companies included SAM Mouldings, Denroy Plastics, Whale Pumps and Magellan Aerospace. Transport, in the form of private hire buses, was organized by the School: each student was allocated to participate in two visits. Students were instructed about Health and Safety protocol, personal protective equipment, dress code and etiquette in the classroom prior to the visits. A member of the teaching team accompanied each group of students (21 students) on the industrial visit.

RESULTS

Of the nine companies that were asked to participate in the module and to host an industrial visit for a group of students, eight were able to take part. Unfortunately, due to timetabling issues, the visit needed to be scheduled for a particular day at a particular time and although all companies contacted were keen to participate in the module, not all of them could facilitate our particular timing request. Six of the companies selected offered to host two visits so that all fourteen student groups could be accommodated.

It is pleasing to report that all students attended at least one of their assigned visits and 90% of students attended both of their assigned industrial visits. This is a much higher attendance rate than is usual for our students taking a classroom-based activity (typically around 65%). If we were to assess the students' participation on attendance alone, this result would indicate that the visits were successful.

Each of the companies, welcomed the students and gave a 10-15 minute presentation on their origin, main products, main suppliers, the manufacturing systems used in the company and the main manufacturing processes and core competences employed in the facility. The majority of the companies stressed to students the importance of the supply chain, the interdependence of buyers and suppliers, innovation and new product development, and the commercial environment that is a feature of today's modern manufacturing workplace. Increasing automation, artificial intelligence, precision manufacture, relatively high labour costs and high energy costs in Northern Ireland also featured in their presentations to students. The relevance of a professional qualification and membership of a professional body for graduate engineers and those at technician was also addressed. The need for continuous lifelong learning and professional development for graduate engineers was often mentioned. In some cases, the host engineer who was giving the presentation was an engineering graduate of Ulster University and when this was the case, the interest levels of the students was increased - they felt more able to relate to the presenter.

The visiting student groups were subdivided further into smaller groups for tours of the manufacturing processes employed in the business and students were instructed to don the appropriate personal protective equipment, e.g. protective goggles, high visibility vests and ear plugs. Students were taught in the specific manufacturing processes as the tour progressed by the industrial engineer. Issues of importance to the specific manufacturing company being visited were discussed and explained to the students: e.g. machine feeds and speeds, waste reduction and elimination efforts, shop-floor organization and management, robotic programming and handling, electronic component part placement and autoclave processes for carbon composites. Resource constraints meant that each student visited only two companies but on each occasion they were exposed to the full breadth of manufacturing subject matters relevant to the industrial engineering discipline.

In the study, the main findings of which are summarized in Table I, students were asked to reflect on and describe their perceptions about industry prior to their first industrial visit. 104 questionnaires were completed by students taking the module providing a response rate of 71%.

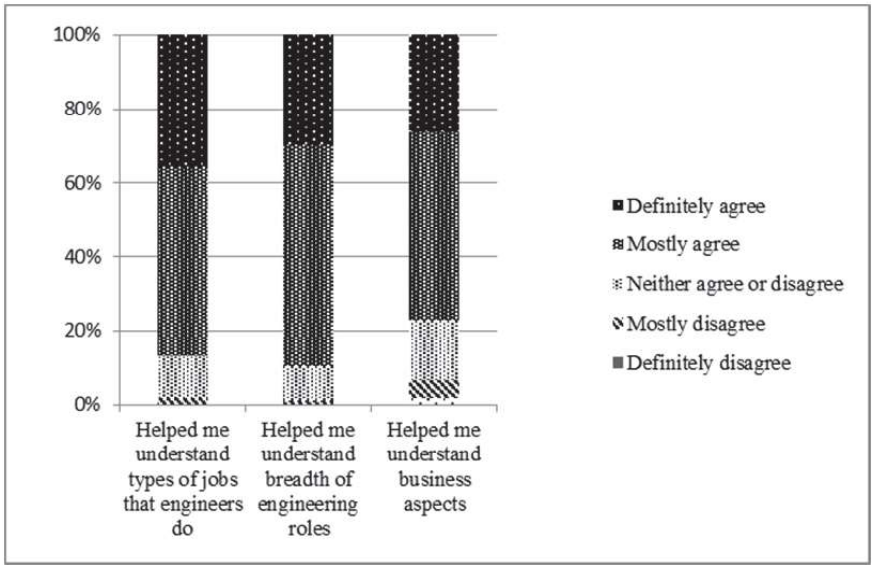
TABLE 1
STUDENTS' INITIAL PERCEPTIONS OF INDUSTRY

Categories	Terms used by students	No. of responses
Design & manufacture	Design, CAD/CAM Manufacturing Quality products	18
Cost focused manufacture	Efficiency, Robots Competitors	17
Production lines	Mass manufacturing Product assemblies	16
Producing goods to customer orders	Customer specifications, Product specifications	13
Exhausting manual work	Dirty, Boring, Exhausting, Manual handling	6

Although 85% of respondents reported that they had been inside a manufacturing company prior to their participation in the module, their replies to an open-ended question about what they thought *industry* was mainly about before their visits, yielded surprisingly limited responses. For those students who provided a response to this open-ended question, the responses were grouped into five broad categories: namely design and manufacture, cost focused manufacture, production lines, production of goods to customer specifications and exhausting manual work; and the response frequencies were noted (some students chose not to engage with this question). The questionnaire was designed so that students could rate the extent to which their learning about the engineering sector had been affected by their visits to industry. Students were asked to if they felt that the visits were worthwhile and to identify the extent to which their initial beliefs had been changed.

Figure 1 shows that: 77% of respondents 'mostly agreed' or 'definitely agreed' that their participation in the industrial visits helped them to understand the business aspect of engineering; 89% of respondents 'mostly agreed' or 'definitely agreed' that their participation in the visits helped them to understand the breadth of engineering roles within industry; and 87% of respondents felt that the visits helped them to understand the types of jobs that engineers actually do.

FIGURE 1
STUDENTS' REFLECTIONS ON THEIR LEARNING ABOUT THE ENGINEERING ENTERPRISE



Programmes in the School of Engineering at Ulster require that all students take either a year-long work placement (paid) period in industry or study year abroad in year 3 of their programmes: this survey sought to establish if the students, as a result of their visits to a particular company, would be *more likely* or *less likely* to apply for a work placement there. The data show that 80% of students would be *more likely*, i.e. positively motivated to seek work placement in a company that had hosted an industrial visit.

In line with the active learning approach adopted in the module, students were asked to reflect on their visits and to identify up to three things in hindsight that they could have done to better prepare themselves for their visits and to suggest up to three things that the module team could have done to better prepare students for their visits. Their responses are summarized in Table II and Table III.

Finally, students were asked if their initial beliefs about industry were *confirmed, changed for the better, changed for the worse* or *overturned* as a result of their learning about industry on this module.

DISCUSSION

16% of the respondents were female which is broadly in line with the participation rate of women in the engineering programmes at Ulster University and in the wider UK society (Women in Engineering Society,UK, 2016). Interestingly, the results showed that the vast majority of students, 85%, had been inside a factory previously, either during period of work experience prior to coming to University, or during an internship prior to commencing the second year of their undergraduate studies. Of the students who had visited a manufacturing organization prior to the visits on this module, almost 70% agreed that two visits were sufficient whereas almost 17% would have liked more than two visits. However, for those students who had never experienced an industrial environment previously, only 44% felt that two visits were sufficient and 38% felt that more than two visits was desirable. Almost all students, 98%, felt that their initial perceptions about industry were 'changed for the better' as a result of their participation in the industrial visits.

The vast majority of students recognized that both their business awareness and their understanding around the breadth of engineering jobs on offer in industry had been enhanced as a result of the industrial visits. This is a positive outcome as both these attributes have previously been identified in as important employability skills that are often lacking in new graduates (7).

TABLE 2
STUDENTS' SUGGESTIONS TO IMPROVE THEIR OWN PARTICIPATION IN THE VISITS

Categories	Terms used by students	No. of responses
Self-preparation for the visit	Read up on company before visit	82
	Read up on assessment before visit	26
Behaviour during the visit	Ask the industry engineer more questions	33
	More interaction with the company engineer	18
	Take more notes of the experience	18

The cost of the transport provided by the School was around £4K, approximately £27 per student for both journeys. Preliminary module results show that the discontinuation rate is very low at 1.4% - well below other modules in the School and the module's failure rate is 6%. Overall, 97% of respondents 'mostly agreed' or 'definitely agreed' that the visits were worthwhile: 94% of the female students agreed with this statement and 83% of the male students were in agreement. It's reasonable to conclude the female students recognized the value of these visits more readily than their male counterparts.

Table 2 shows that, on reflection, many students felt that they could improve their experience by preparing themselves more fully before the visit and then by being more 'engaged' with the host engineer during the visit. This demonstrates that the visits facilitated an improvement in the students' self-awareness.

TABLE 3
STUDENTS' SUGGESTIONS FOR THE MODULE TEAM TO ENHANCE STUDENT PARTICIPATION

Categories	Terms used by students	No. of responses
Visit organization	Allow students to choose which company to visit rather than being assigned particular companies	13
	Have more time in the company during the visit	6
Assessment issues	Assessment criteria to be published in advance of the visit	58

Table 3 shows what actions students believed the module team could take to improve the students' participation and learning. These were concentrated on the module team providing students with more explicit assessment criteria beforehand and allowing students to self-select the visits that they would participate in, rather than being allocated to a particular company visit.

CONCLUSION

This paper reports on a study carried out on students taking an industrial engineering module at Ulster University. The module was designed and delivered in partnership with industry so that students would experience active participation in an industrial engineering real-life scenario. Results confirm that student engagement and participation levels in the module were much higher than in other comparable modules in the School. Students' perceptions of industry and of the 'value' of industrial visits has been reported.

Preliminary results indicate that students viewed the industrial visits very positively and found them a worthwhile and valuable activity that significantly enhanced their learning on the module. The module team believes that the students' employability skills have also been enhanced by their active participation in the industrial visits in that students have experienced at firsthand real-life manufacturing environments where business and commercial decisions are an integral part of the work of the industrial engineer and the engineering enterprise. The students' positive feedback about their learning on the module outweighs the, not insignificant, logistical challenges associated with organizing the visits, arranging transport and dealing with groups of students off campus.

REFERENCES

Archer, W., & Davison, J. (2008). *Graduate employability: What do employers think and want?* London: The Council for Industry and Higher Education, UK. Retrieved from https://aces.shu.ac.uk/employability/resources/0802Grademployability.pdf

Bombardier aerospace UK. (2017). Retrieved from https://uk.bombardier.com/en/aerospace.html

Cusea, J. (1992). Collaborative & cooperative learning in higher education: A proposed taxonomy. *Cooperative Learning and College Teaching,* 2(2), 2-4.

Denroy Plastics Ltd. (2017). Retrieved from http://www.denroy.com/

Dowling, A., & Brinded, M. (Eds.). (2017). *Engineering UK 2017, the state of engineering*. London UK: Engineering UK.

King, E. (2007). *Educating engineers for the 21st century.* London: The Royal Academy of Engineering. Retrieved from https://www.raeng.org.uk/publications/reports/educating-engineers-21st-century

Magellan aerospace. (2017). Retrieved from http://magellan.aero/

Montupet UK. (2017). Retrieved from http://www.montupet.fr/english/northern-ireland-belfast-43/northern-ireland-belfast.html

Morgan, M., & O'Gorman, P. (2010). (2010). Developing industry ready engineers: A regional university perspective. *Proceedings of International Conference on Engineering Education,* Gliwice, Poland. 74-82.

Non-continuation rates: UK performance indicators 2016/17. (2017). Retrieved from https://www.hesa.ac.uk/news/non-continuation-tables#non-continuation

O'Gorman, P., & Morgan, M. (2016). Facilitating effective teamwork in undergradute engineering group projects. In P. Tiernan (Ed.), *Proceedings of the 33rd international manufacturing conference* (1st ed., pp. 252-257) University of Limerick.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Higher Education,*

Ryobi Aluminium Castings UK. (2017). Retrieved from http://www.ryobi.co.uk/

Springfarm Architectural Mouldings. (2017). Retrieved from http://www.sammouldings.co.uk/

Subject overview. (2017). Retrieved from https://unistats.ac.uk/Subjects/Overview/10007807FT-6239

The accreditation of higher education programmes, 3rd edition. (2016). Retrieved from http://www.engc.org.uk/engcdocuments/internet/Website/UK-SPEC%20third%20edition%20(1).pdf

The Institution of Engineering and Technology. (2017). Retrieved from https://www.theiet.org/

The Institution of Mechanical Engineers. (2017). Retrieved from http://www.imeche.org/

The National Student Survey. (2017). Retrieved from http://www.thestudentsurvey.com/

The skills shortage, mind the gap. (2015, 11th April 2015). *The Economist,*

The UNISTATS website. (2017). Retrieved from https//unistats.direct.gov.uk/find-out-more/key-infornation-set#kis

Universities and Colleges Admissions Service. (2017). Retrieved from https://www.ucas.com/corporate/data-and-analysis/analytical-data-services

Varney, D. (2008). *Review of competitiveness of northern ireland.* (). Belfast: Retrieved from http://www.hm-treasury.gov.uk/independent_reviews/varney_review/varney_competitiveness_index.cfm

Wakeham, W. (2016). *Wakeham review of STEM degree provision and graduate employability.* (). London: Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/518582/ind-16-6-wakeham-review-stem-graduate-employability.pdf

Whale Pumps. (2017). Retrieved from https://www.whalepumps.com/

Women in Engineering Society. (2016). Retrieved from http://www.wes.org.uk/content/wesstatistics