Teaching self-awareness, diversity and reflection to support an integrated engineering curriculum augmented with problem and scenario-based learning.

Tilley, E[1]
Teaching Fellow, UCL Engineering
University College London
London, United Kingdom

Peters, J
Director
Katalytik
Christchurch, United Kingdom

Mitchell, J E
Director of the Integrated Engineering Programme, UCL Engineering
University College London
London, United Kingdom

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INTRODUCTION

There is evidence that academic institutions in the engineering education community are starting to address the growing concerns that engineering education is not progressing to meet a global need for well-rounded engineering graduates. Well-rounded engineering graduates have been defined as those who supplement their good academic performance record with high level analytical and critical thinking skills, communication and teamwork skills and a sound understanding of engineering and business practice [1]. At University College London (UCL) steps are being taken to change and revamp the approach to teaching engineering and to commit to an integrated engineering programme created in part to soothe the concerns of UCL's industry partners.

A university level teaching environment based on Problem Based Learning (PBL) is being established across the Faculty of Engineering. Students are initially introduced to the fundamental elements of engineering design and thinking, how to work successfully in teams, effective communication and professional practice, prior to participating in 1-week long intensive "Engineering Scenarios", as an effective strategy to address the growing need for high performing engineering graduates with a well-rounded set of skills [2]. The PBL environment is being strengthened by a programme developed around the strengths-based learning principals of Gallup's StrengthsFinder2.0 [3] to give students the tools and vocabulary to help them identify, fully explore, utilise and develop their natural talents and personal strengths throughout their engineering education prior to graduation. Through such exercise, students become familiar with a common language, used by employers, and develop a heightened awareness of each other's potential to contribute to the team's goals. In turn, students are more able to deal with and possibly limit, the occurrence of problems associated with leadership [4] and assignment of roles, division of responsibility, time management, and communication often experienced when working in teams. Additionally, addressing this level of self-awareness, students build mutual respect, and it will produce graduates that are more easily attuned to the diversity and inclusion policies within companies that essentially are founded on respect.

New Criteria for Engineering Graduates

The criteria for engineering graduates, used by industry leaders, to evaluate individual employability and value as potential employees has been redefined and updated to reflect the needs of society and the interdisciplinary approach to global engineering problems. It has emerged (through consultation and industry surveys) that future engineers will need to be equipped with skills that have not been previously emphasized in engineering curricula [5]. A major finding is the need to not only increase the amount of time and emphasis placed on the teaching of supplementary skills sets, those directly

related to professional (engineering and business) practice; such as communication and teamwork; analytical, creative and critical thinking; integrated and holistic engineering design, but also the primary pedagogy.

Some would argue that the engineering education community has been slow to respond to the expressed needs of industry but it is becoming increasing apparent of the momentum that is building across forward thinking academic institutions, like UCL, that are starting to make progress and significant contributions. Supporting examples include The Massachusetts Institute of Technology (MIT) CDIO (Conceive Design, Implement, Operate) Initiative [6] and its Gordon-MIT Engineering Leadership Program in USA, the Project Management in Practice course at the Universitat Rovira in Virgili, Spain, the Engineering Leadership Advanced Award Scheme for Undergraduates presented by the Royal Academy of Engineering in the United Kingdom and the Department of Engineering Education at Virginia Tech in the USA [7]. Such international programmes, awards and courses are grabbing the attention of and creating pathways for others academic institutions to follow [8].

1 UCL TEACHES ENGINEERING DESIGN, CRITICAL THINKING, PROFESSIONAL PRACTICE, TEAMWORK AND COMMUNICATION TOGETHER

Engineering teaching at UCL is evolving to ensure that students learn how successful teams work and to improve their communication skills alongside a formal introduction to engineering design and critical thinking. The IEP will offer students an opportunity to get involved in designing integrated engineering solutions to problems and scenarios presented in their Year 1 modules alongside learning a variety of good team-working tools and strategies. Problem and scenario-based learning is regarded as an effective way to engage students and build enthusiasm about their engineering education and has proven to decrease the rate of student attrition. Evidence of this has been provided by the Civil, Environmental and Geomatic Engineering Department at UCL in recent years since they've redesigned their curriculum [9] to give more significance to engineering design, context and professional practice skills supported by a series of 1-week problem-based "Scenarios" where the students work in teams to design a solution to a practical engineering problem.

"Learning by doing" has been widely proven to be successful with students, as they often provide positive feedback when asked to reflect on their experiences and perceived learning outcomes. Often communicated in their feedback is their difficulty of learning a new concept when not provided with a proper introduction, useful research material or resourcing guidance and time to prepare prior to engaging in, executing and completing the associated task or assignment [10]. Educators who offer these types of modules understand this and have designed the teaching material to provide students with an opportunity to prepare for what they will be expected to learn and become proficient. This is true of both technical and non-technical tasks and assignments. Reflection is a critical part in helping the students appreciate and evaluate their own learning and understanding around new concepts and tasks. Reflection may also help the students relate to the overall purpose and perhaps lead the way for personal autonomy and mastery on the material of study [11]. Embedding personal reflection into the curriculum and course assessment also teaches students a useful technique and helps them to develop a personal routine, employed by senior managers and leaders and often required for professional certification, for record of continual learning and development and hence offers a further tool alongside knowledge of teams and communication to support engineering learning.

Embedding these learning strategies into the curriculum during the first term of a student's engineering education is expected to improve their professional practice capabilities, understanding of engineering context and connectedness to their eventual roles and responsibilities as future practicing engineers. UCL are attempting to go above and beyond this single tactic and are committed to providing students with a meaningful introduction to new learning concepts, both technical and non-technical, prior to having them put it into practice in such PBL and "Scenario" modules. Their individual success in these styles of undergraduate module and understanding of the taught material is expected to increase as a consequence.

2 STRENGTHSFINDER2.0: LEARNING ABOUT TEAMWORK AND COMMUNICATION THROUGH SELF-AWARENESS AND PERSONAL STRENGTHS ASSESSMENT

There are many tools for developing self-awareness that help with the analysis of traits and predisposition towards certain behaviours. Some tools assess behaviours in the presence of other behaviour 'types'. By focusing on personal strengths, i.e. positive traits, as presented by the methodology inherent to StrengthsFinder2.0, students are able to exercise their strengths in all walks of life and gain confidence in using them and learn to appreciate the impact they may have on others, both positive and negative. Giving students an opportunity to identify their own personal strengths, through the use of the online assessment tool such as StrengthsFinder2.0, and mapping a whole team's strengths can help identify potential skills gaps. For example during the initial development and piloting phase of the project – a strengths proforma for each team was created. One team found they had no relationship building strengths, another, randomly created team found they had only executing strengths. This highlighted to the team, early in the Scenario module, that the team's drive toward getting on with the work might leave little room for planning. During the reflection the team commented that it had been hard but knowing where their collective weaknesses lay, helped them make sure they planned their work.

Many tools for personality, 'type' and/or behaviour assessment have been developed in the last 50 years; many based on extensive research and analysis and often marketed by leading business schools and consultancies (for example Harvard, Hay Group, Gallup). One of the earliest was the Belbin model [12] – offering a profile across six different 'types'. During the research completed by the HE STEM Set to Lead project it was found that of those engineering faculties doing any team or leadership teaching that Belbin was the most widely recognised and used in UK engineering education to support team work and the Adair model, which has an association with the University of Surrey in the UK [13], was used to support leadership insights. Another well-known tool and widely used currently in industry, is Myers-Briggs (MBTI); it is also used in education, particularly in North America [14]. MBTI offers 'type indicators' or profiles and has been analysed against professions and as a career predictor. Using this as a reflective and investigative tool though does not help to predict the types that are needed in emerging engineering fields.

All of these tools categorise people based on historic research, which may not be valid now or in the future as a defining profile for an 'engineer'. Engineering is a broad sector requiring many diverse technical and interpersonal skills and increasingly, profiles that have been typically associated with engineers are less desired by current employers who want strong collaborative, strategic thinking and relationship building skills. Arguably the tool that is chosen to use in an engineering education programme is arbitrary [15], simply offering highly accessible vocabulary and a common language for students, educators and tutors to use to discuss team and leadership behaviours. StrengthsFinder2.0 was chosen as a pilot exercise at UCL based on input and advice from leadership experts and industry partners during the HE STEM funded Set to Lead project [16]. The positive feedback and successful outcomes relayed by those associated with the HE STEM Set to Lead project supported the use in an extension pilot project.

The purpose of using a tool to help students appreciate their strengths and natural inclination for certain behaviours is to give them a clear set of vocabulary to discuss team working and to help them form a non-confrontational discussion around what others are or are not doing in the team. StrengthsFinder2.0 is currently being used across the USA in the student environment and there are supporting materials in StrengthsQuest [17].

3 HOW UCL ENGINEERING IS USING STRENGTHSFINDER2.0 AND ITS CONTRIBUTION TO THE STUDENTS' LEARNING AND SKILLS DEVELOPMENT

The StrengthsFinder2.0 based team and leadership workshops were piloted in two phases, with self-selected Electronic and Electrical Engineering (EEE) students in 2010, during the development phase, with a separate self-selected cohort in 2011 and most recently in the autumn term of the 2013 academic year with the whole Year 1 using an existing immersive project based engineering Scenario module that has been consistently delivered for the past five years [18]. Students were prepared using the team and leadership workshops prior to working in groups to address a design problem with the

aim of producing, within a set period of time, a solution to the specified problem set. Although it is understood that the brief in any given Scenario module may be narrower than others, they should all allow for a number of different successful (i.e. to some extent solving the problem) designs.

In preparation for the Scenario week, the EEE Year 1 students were provided with: a formal introduction to successful team-working skills; leadership types and methods; the importance of considering diversity and inclusive engineering when working in a team; and using brainstorming to advance their engineering design solutions. Each student was given a personal copy of the StrengthsFinder2.0 book and individual access to the online assessment tool. They were then asked to submit their Top 5 Strength results so that they could be collated and categorized under the four themes specified by Gallup research into leadership styles, namely: 'Executing', 'Relationship Building', 'Influencing' and 'Strategic Thinking'. The amassed results, representing approximately 70% of the cohort, showed that the majority of students were in fact natural 'Executors', with many having 'Achiever' and 'Competition' as one of their Top 5 Strengths. The category that was the least represented by the Top 5 Strengths of the student cohort was 'Relationship Building'. These results are perhaps unsurprising, as many might argue that students successfully enrolled in engineering education are inherent 'doers'.

The preparation workshops were interactive and used video clips - that had been specially prepared during the pilot phase - of industry leaders talking about strengths, team skills, inclusion and leadership. Other background research was presented to the students that consistently show that communication and teamwork feature high on the list of key skills that employers look for (see recruitment sites such as Targetjobs.co.uk and Graduates.co.uk).

At the start of Scenario week students were assigned to teams according to the time that they arrived at the first class. Each team was given a team strengths sheet and it was suggested that they consider their own Strengths profiles and identify the collection of Strengths as represented by the team members to identify any gaps. Any observed gaps in the teams Strengths assessment were then presented as points for collaboration.

The videos of industry leaders were used to illustrate how to assess and use your strengths. One leader spoke of how she had learned to manage her natural strength of 'Competition', to be competitive for her team and not just for herself. Consideration was given to a control group, but the practicality of creating a control group that was isolated from the rest of the cohort meant this was not possible [19].

The workshop preparation focused on communication as being critical for effective team-working and was underlined in the commentary from the videoed leaders and background research from recruiters. Additional resource was provided in the lead up to the Scenario week on effective communication strategies and the need for dynamic teams which allow for each team member to take on leadership roles at relevant times in the project or regarding specific tasks that each feel best suited for. This was reinforced by introducing the students to taking 'leadership beyond authority'[4], a means of taking on a leadership role as a result of their own passion, realized vision or purpose for something they want to make a difference and can enrol others to support and contribute to: this is done regardless of the title they hold. This aligns well with the learning theory presented by Daniel Pink, which calls upon a person's sense of purpose to intrinsically drive their efforts for autonomy, eventually leading to mastery once the time and commitment to practice and training has been exhausted.

Students were introduced to an Intentional Learning Plan (ILP) during the preparatory workshops and encouraged to consider their aspirations for the next 1, 3 and 5 years and to consider how and who they might talk with to help realise those ambitions. It was repeatedly stressed that the ILP is a 'live' tool that will help collate evidence to support student's capabilities that could be used when preparing for interviews.

The UCL EEE 2013/2014 Year 1 cohort has a (typically) low representation of women students, thus no statistically significant analysis on gender differences can be performed. However, one of the driving forces behind using a tool to enhance self-awareness is to improve mutual respect among students and offer a vocabulary to voice and de-personalise frustrations. The hope is that this will build a more inclusive and supportive environment for minorities, especially female students. As this is a pilot project for the first year of the IEP, which would include students across the faculty, regardless of specified discipline, the analysis tools are currently being developed to provide insights into gender (as well as cultural) differences.

Critical to the design and success of the Scenario module is the feedback session that was scheduled at the end of the week and completed in a workshop format with the full cohort present. Each student provided individual feedback anonymously on what they felt was a success, a challenge and what they would change. They were asked to reflect and provide feedback, under the three designated categories, on their teamwork experiences and technical aspects of the Scenario tasks.

It was clear from the feedback that the students were provided with a sufficient amount of research and preparation material to understand the technical aspects of the Scenario, they did however comment on their difficulties with the analytical and mathematical modelling involved in designing the optimally performing electromagnetic lifting coil. With regards to how the students responded to working in teams, not of their own-choosing, communication was listed as one of the challenges experienced amongst their teammates but many wrote of their enjoyment exploring different roles and responsibilities during the week as a result of their personal strengths and interests supported by the results of their personal assessments. Not all teams chose to have an overall team leader, which lead to varying successes with regards to both their technical performance and individual teamwork experiences. However, most teams that did assign a team leader based on their natural talent for communication and strengths based in 'Relationship Building' provided positive feedback on their overall teamwork experience and technical performance.

4 MOVING FORWARD

The intention is to now monitor progress and confidence of students in their team-working and to have students revisit their strengths. The purpose of the StrengthsFinder2.0 tool is not to make students conversant with the tool per se, but to use it to facilitate learning and discussion around skills and skills gaps.

Assessing student's overall strengths will offer suggestions to engineering educators, tutors and those involved in the design of the new curricula ideas for supplementary workshops and seminars that will enable students to practice these skills outside of their weekly timetable. Further, it might also provide an opportunity for students to learn from industry leaders on the need to appreciate those who have these natural talents. For example, for executors to learn the importance and value in strategic thinking and to inculcate a new perspective on the advantages of good partnerships, tolerance, respect and the need to develop some competencies and an evidence base in these areas.

Following the pilot, a 'Train the Trainer' workshop for self-appointed Student and Academic Champions on the StrengthsFinder2.0 tool will both offer tutors and engineering educators some continuing professional development and the opportunity to develop their own greater personal insights. It will also help to ensure that once the IEP is launched that academic staff and tutors are in a stronger position to support student learning and communication.

5 CONCLUSIONS

Students were exposed to Problem and Scenario-based Learning, delivered with the three tiered approach (i.e. introduction, practice and reflection) and were supported by using a personal strengths assessment. This gave students the vocabulary to have a meaningful conversation around team roles and team performance. The aim is to produce more highly skilled, technically confident and well-rounded engineering graduates.

The importance of introducing communication and team-working early in the undergraduate first year so that students are practising and developing their own skills and reflecting on their role and performance at every step has been recognized and encouraged in engineering at UCL. Embedding learning about self-awareness within engineering education is seen as a vital part of shaping the workforce, driving engineering research into new realms of discovery and developing leaders of tomorrow. The biggest issue for employers recruiting graduates into today's workforce, ahead of technical competency, is communication and teamwork [1]. Educating about team-working and leadership is about tackling existing engineering cultures to help students move closer to the ways in which industry is working and research is being lead. Additionally, at UCL, continuous work is in progress to place a greater emphasis on this through concerted consideration of other available equalities training such as those unmasking unconscious bias and guiding inclusive engineering. Inclusive engineering, both in working with colleagues and in delivering solutions and products, is a growing issue. Students with an appreciation of inclusivity in an engineering sense will be more highly

valued than those who don't have that appreciation or experience of working in diverse teams. By using industry used tools, such as StrengthsFinder2.0, to enhance student communication and collaboration it will be possible to work towards closing this gap.

Industry and society need engineering educational advocates – industry needs to be drawn into contributing more to the education of engineering cohorts globally. Collaboration with engineering educators and university administration is vital to realising the full potential and benefit of giving significance to and formal teaching of supplementary non-technical skills not yet covered in engineering curricula. Such skills can only be realised in students through the positive and continuous promotion of self-assessment and self-awareness in the form of a strengths based model, such as StrengthsFinder2.0, to help students understand their natural abilities, most favourable roles within dynamic teams and progression into engineering as a profession. Increasing the opportunity for engineering students to become better self-aware accelerates their individual learning. Educators who offer modules that inherently strive to reach a student's sense of purpose through effective preparation, supplementary teaching programmes to introduce and develop professional and communication skills, problem and scenario based learning, diversity and inclusive engineering and embedded personal and technical reflection, facilitate a pathway to a students' autonomy and associated mastery.

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