Evaluating Professional Skills Development Across the Engineering Undergraduate Degree Programme: An IEP Review

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Abstract
The advancement of technical competency has traditionally been at the centre of engineering pedagogy in university education, however, the increasing emphasis on the need for professional skills by accreditation bodies and employers has seen pressures on the higher education system. University institutions worldwide have taken this on but in order to do so have had to shift their pedagogical approach. The attainment of technical and theoretical knowledge has long suited a teacher-centred learning style where students receive information from the educator and are expected to assimilate and absorb knowledge passively. However, the attainment of professional skills implies the need for application in professional or pseudo-professional settings in order to ascertain its procurement. This has led to the implementation of active learning or student-centered pedagogies where students play a more participatory role and hands-on role in their learning. The award-winning Integrated Engineering Programme at University College London celebrates 10 years of existence this year and has been seen to be one of the global leaders in the embedding of professional skills within the engineering curriculum. But how effective has it been? This research addresses the following questions using interviews and focus groups:
1. What are the key issues/commendations staff have of students' application of professional skills within an engineering context?
2. What could be incorporated into year 1 learning to better prepare students for subsequent years of study?
3. How is skills-based teaching perceived by students as they progress through their degree?

Keywords: Engineering Professional Skills, Engineering Education, Integrated Engineering Programme

Introduction

Here in the UK, there has been a gradual but noteworthy shift in engineering curricula with the aim of improving an engineer's teamwork and communication skills. Several institutions have revised their curriculum to highlight technical communication and engineering teamwork competencies in some form. Such universities include Kings College London Centre for Research in Education in STEM, Manchester University via their Science and Engineering Education Research and Innovation hub and Aston Engineering Education Research Group, among others (Hauke, 2014). With that said, there is little data available at this moment that demonstrates the impact of this pedagogical shift on efficacy of the engineer's professional skills in the workplace, however a paper released by the *Royal Academy of Engineering, 2019*, suggests that progress has been shown in closing the skills gap (Perkins, 2019).

An institution that is reported to be leading the way in engineering curriculum reform in the UK is University College London (UCL). In 2014, the UCL Faculty of Engineering Sciences made comprehensive revisions to its curriculum and made it a focal point to account for the enhancement of professional skills, with particular emphasis on teamwork and technical communication skills of engineering students via the Integrated Engineering Programme (IEP). As shown in Figure 1, students enter through their home departments (e.g. Chemical Engineering) via the 3rd year Bachelor of Engineering (BEng) or 4th year Master of Engineering (MEng) undergraduate programme where they then take on their departmental modules alongside IEP modules. In the first year there are three IEP modules – Engineering Challenges (also known as the Challenges or ENGF0001), Design & Professional Skills 1 (DPS1) and Mathematical Modelling and Analysis 1 (MMA1 or ENGF0003). These modules are managed by the central IEP team under the direction of Prof. Emanuela Tilley.

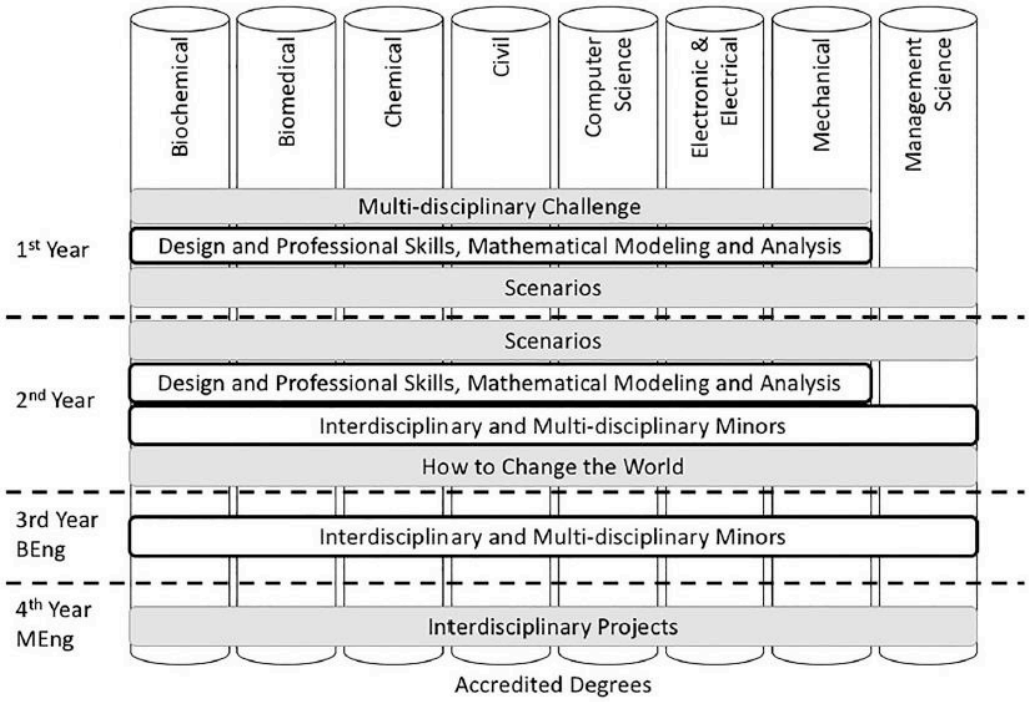

Figure 1: Overall Structure of the IEP and the Engineering UG Degree.
From Mitchell et al. 2019

Second year modules are predominantly department-managed with the exception of MMA2 (or ENGF0004) and How To Change The World (HTCTW), which are IEP managed. Third- and fourth-year modules shown in figure 1 are departmentally managed but adopt an IEP pedagogy via the use of certain practices such as PBL and technical communication development (John E. Mitchell *et al.*, 2019).

This study focuses on the impact of DPS1 on subsequent years of study. On this module students are taught and assessed by engineering communication experts on their ability to communicate their work via lab reports, specifications and codes as well as design reports as well as a range of presentations including demo, showcase and powerpoint. Another component of the module involves training engineering students to present their work to audiences with different technical backgrounds, as well as different career stages (e.g. PhD students). Students on the programme are taught and assessed on how to tailor presentations to various audiences (John E. Mitchell *et al.*, 2019). Students are also taught how to work in teams and apply these teachings in other IEP modules such as the Challenges as well as other parts of DPS1, such as 1st year scenarios.

The first-year scenarios are two-week-long P(j)BL-based projects in which students work in teams to find a solution to a real-world issue. In Biochemical Engineering, for example, students work in teams of 4-5 students to solve manufacturing issues related to shelf-life of a product and scale-up of production to meet consumer demands. During the week they visit manufacturing sites and meet with industry experts in the area, who are also involved in assessing the teams' technical solution. The teams are also assessed on their final presentation and teamworking capabilities. The direct involvement of industry in academia has been shown to have a positive impact on student drive when adopting a P(j)BL approach (Kaushal, 2016).

The IEP was designed and implemented to address directly the needs expressed by stakeholders such as employers, government and accreditation bodies for an engineer to be able to effectively communicate their work to various audiences and work competently in teams and whilst a number of UK institutions have implemented similar revisions to their curriculum none have done so on the same scale as UCL. As the IEP celebrates 10 years of existence, what is needed at this stage is to ascertain whether or not these reforms are effective as students progress through their degree.

Aims of This Study

The aim of this study is to gather the perspectives of staff across the departments that take DPS1 and staff that are responsible for 'flagship' modules for the 2nd and 3rd/4th year cohorts regarding their assessment on teamwork, writing and presentation skills development across the UG degree programme. In this study a 'flagship' module is defined as a key module where teamwork, writing and presentation skills are emphasised according to the learning outcomes – so for the 2nd year cohort, that would be the Design & Professional Skills 2 module (DPS2) and for 3rd /4th years, that would be the final year Design/Project module. Departments involved in this study are: Biochemical Engineering, Biomedical Engineering, Chemical Engineering, Computer Science, Electronic and Electrical Engineering (EEE) and Mechanical Engineering. Civil Engineering's DPS1 module is departmentally managed and is therefore not part of this inquiry.

On a personal note, as the IEP faculty lead of DPS1, a key goal is such that the findings of this research primarily help inform the IEP of areas of improvement to better support engineering students' skills development. A secondary goal of this research would be in aid of the improvement and development of pedagogic practice among staff on the DPS1 module and beyond and sharing of best practice.

This study aims to investigate the following research questions:

- What are the key issues/commendations staff have of students' abilities to work in teams, write and present their work throughout the degree programme?
- What could be incorporated into the 1st year DPS1 module to better prepare students for subsequent years of study?
- How is skills-based teaching perceived by students as they progress through their degree?

Further background and the methodological approach used in this study can be found in Nweke, 2021. Note that the findings presented in this study are a continuation of those presented in Nweke 2021. Due to word count limitations, the third research question on perceptions of skills-based teaching will be published in a separate paper.

Findings and Discussion

Assessing Teamwork

As found in Nweke 2021 whilst careful selection of members within a team can aid in how a team functions, there are still uncertainties concerning team cohesion and conflict resolution capabilities once the team is put together and how this is assessed. General practice reported in literature suggests that students are awarded a singular team mark, and whilst this may favour members that are less engaged, it puts the more capable students at a disadvantage, which has been reported to negatively impact team cohesion (Grammenos *et al.*, 2020). Departments across the faculty have noticed this and as a result have adopted varying approaches to promote team cohesion, particularly in the early years of study:

> *"One thing that they also have to submit within the week is a reflective diary. Each day it's designed to trigger them to think about both how the project's going, but also how they're working as a team… the questions in the diary are - what isn't working your team? What can you do personally to make that better? To try and make them take a bit own of ownership of their team because I found sometimes in teams that don't gel you get students who just go and take a back seat and then everyone takes a back seat and then nothing gets done. So I wanted to work on them taking ownership of their issues within a team."* (John, 2nd year)

> *"We've got systems called green lights… (we've) got these wonderful automated spreadsheets where whenever you meet a student, you flag it green, amber, red.. Every encounter ..any teaching assistant or staff makes with the student you give him green, amber, red and so you can see patterns in the data throughout the terms. And it literally says green is good… if you want to help them with (anything)…then they get Amber, and if they've just been misbehaving or not contributing, or you know they're just absent, it's just a red, which means that you know you get 2 reds in a row, you get called into my office."* (Dean, 2nd year)

> *"If there are students that weren't attending or weren't contributing, we generally then got in contact with them and ask them why? What are they doing? What's their contribution and particularly the last scenario they couldn't that they couldn't get the group mark unless they contributed an individual component. So close supervision, close contact points to try and maintain contribution, incentivizing an individual contribution to get the group mark and moderating marks for those that contribute less."* (Ryan, 3rd year)

Although the approaches taken are different, what is common across the departments is the emphasis on evaluating individual contributions within a team as a means of aiding team cohesion, coupled with assessing the team deliverable itself (e.g. a written report, presentation etc.). The varying approaches however, could be a contributing factor to any possible retrogression in teamwork skills development (Adams and Laksumanage, 2003).

The use of web-based/ software for teamwork has been reported in literature and one that has proven to be reliable on parts of DPS1 and has subsequently been rolled out on other IEP and departmental modules is the use of the software tool known as IPAC (Individual Peer Assessment of Contribution to group work) (Garcia-Souto, 2017).

> "*I do this IPAC thing, which is the individual peer assessment contribution and initially it started as a way of getting the students more engaged because they know that they cannot just hide without doing anything and also to improve the dynamics because now there is accountability within the group."* (Jackie, 2nd/3rd year)

Spearheaded by Dr Garcia-Souto of Medical Physics & Biomedical Engineering, UCL, the tool is described as a "method of assessment that differentiates individual marks based on the effort /professional behaviour of each individual as assessed by their peers. The IPAC methodology addresses the staff and students' concerns of mark fairness, as well as discourages "passengers", engages students, and gives a better overall students experience."(Garcia-Souto, 2017). This software allows students within a team to quantitatively rank their peers' contributions and provide written feedback to support the ranking. Staff on the course are able to monitor these entries daily and the values generated are used as part of the teams' marks. Both students and staff alike have provided commendations on the efficacy of this tool, with 92% of students being in favour of the use of this tool as a means to assess teamwork in a fair way (Grammenos *et al.*, 2020). However, there are concerns from staff that students may not be aware of what standard of contribution is expected from them and when to flag up issues with a member of staff and these may cause issues within a group, particularly in latter years of study:

> "*Yeah and also maybe incorporating into some of the learning that you do strategies on how to overcome problems within teamwork so that then they don't have to flag it up.. but they think what strategies have I got? How to do it so that they could maybe do that a bit more themselves? So that they get into less problems as they proceed through the project in the third year."* (Steven, 3rd year)

As reflected in literature, these findings perhaps highlight a gap in the current assessment of teamwork on DPS1 – how to assess conflict resolution, which was a concern expressed by staff:

> *"If there is a group with a really bad problem, but they actually work through that problem and come out the other side I mean, that's fantastic, but it's hard to actually reward the students for doing that."* (Robbie, 3rd year)

In a study carried out by Wang and Wu, 2020, one of the most effective ways of assessing conflict management and resolution is using systematic questioning in either interview or documented format, that allows the participant to: 1. Identify the reasons for the conflict, 2. Describe the conflict itself 3. Recognise their contribution to the conflict (whether good or bad), 5. Identify the solution 6. Recognise their contribution to the solution, 7. Reflect on what could have been done differently. This has proved effective when used by employers for the purposes of recruitment (Ludewick *et al.*, 2020), however, what is unknown is whether this level of granularity can be feasibly integrated into the current DPS1 assessment format. It is perhaps worth considering the integration of this (or a similar) approach in combination with the successful IPAC approach. This should allow for a more comprehensive assessment of teamwork that will ensure that important metrics used by employers are effectively evaluated as students progress through their degree.

Presentation Confidence

What was observed in this study is that despite the ample practice students get to present in various contexts, staff still highlighted issues related to presentation confidence:

> *"Well, you got the usual tacit and non-tacit behaviours of your teams, so you've got certain people who are always quiet and they don't want to present."* (Dean, 2nd year)

> *"I think probably the biggest challenge we have is nervousness. And you know, even some of the really good students who can put together a good presentation, it's nerves."* (Robbie, 3rd year)

Although not commonly reported in literature, it has been raised in some studies, particularly internationally (Brocato *et al.*, 2015). In a study carried out by Mohamed and Asmawi, 2018 on understanding the main challenges engineering students face with oral presentations in universities in Malaysia, 37% of the students that participated in their study reported their main issue to be a lack of confidence, which was the highest percentage attributed to any of the challenges, some of which included a lack of preparation (12%), content understanding (8%) and other challenges related to the presentation technology and time management.

Brocato *et al.*, 2015 observed similar challenges in Mississippi State University and reported on the use of theatre workshops as a way of tackling presentation confidence issues with engineering students. These workshops took place a week before the students' first presentations of the year and used expertise from individuals with more than 30 years in theatre and musical performance. It involved exercises that addressed controlled breathing, phonation, projection and fighting self-consciousness. More than 50% of students fed back that the workshop helped to improve their confidence and was also reflected in the increase in average marks for presentation assignments for that year.

A further approach reported by Cochrane and Donoghue, 2008 involves the use of a software program called the *Virtual-i Presenter* (*ViP*). Using this program, students are able to create, view and evaluate their oral presentations using their PCs/laptops and webcam outside of class time. The software is able to recreate how the student's presentation would be delivered

in class and aids in improving their skills by allowing them to watch themselves back, practice repeatedly and receive feedback from peers and academics. Surveys showed that students were able to practice 4 times more than usual and almost 65% of students preferred the use of the online tool compared to live presentations.

Given the uncertainty of the current climate and the growing need to be able to quickly adapt to online teaching and learning environments, the use of a software or online tool that students can use to practice their presentation and improve their confidence is generating more appeal than traditional face-to-face approaches (Motogna, Marcus and Molnar, 2020). In recognition of this, as of the coming academic year, DPS1 has incorporated the use of an online tool, similar to the one reported by Cochrane and Donoghue, 2008 called *GoReact*. This tool carries all the aforementioned functions of *ViP*, with the additional benefits being the ease of its integration onto the Moodle platform as well as the ability for staff and peers to join a student's live presentation session and the ability to have different presenters in one virtual room, mimicking what was practiced in face-to-face presentation assessments pre-COVID-19. The hope is that the implementation of this tool will not only allow for ease in transition to online presentations if another lockdown occurs, but it will serve as a long-lasting resource for students to use to continue to enhance their presentation skills, particularly relating to confidence.

Another possible reason behind the lack of confidence within the engineering education context could be attributed to English being a second language and the perceived feelings regarding students' command of English, even in the latter years of study (Stapa, Murad and Ahmad, 2014). Of the top ten nations that produce engineering graduates, over 85% speak English as a second language and of this number, almost 50% are from Asia, more specifically East Asia (WorldAtlas, 2021). This is reflected in the annual uptake of students in the Faculty of Engineering Sciences at UCL, with a similar proportion of students coming from the East Asian region and has been recognised by staff in this study to have been exacerbated by remote learning:

> *"If you're the one student on a European time zone and you have five team members on a Far East time zone ... the group meet without you or communicate in a different language in a separate chat channel ... So there might be some challenges there where people are more nervous to speak English 'cause they're doing it less."* (Ryan, 3rd year)

As reported in literature, many engineering educators have recognised the difficulties associated with bringing students up to the same technical standard, let alone the same standard of English and many recognise that the onus cannot be on the academic alone and that there is a need for external support from those with specific expertise in this area (Poongodi and Periasamy, 2020). A study by Thakur, Kaur and Thakur, 2013 recognised this need and outlined specific steps that those trained to teach the English language to engineering students could take to help improve communication such as the use of technical vocabulary, correct grammar, sentence construction, among others. And whilst the study was able to demonstrate a general improvement in language skills, what seemed to be missing was the link between the English language instructor and the academics in the engineering departments for engineering technical language proficiency.

To address this, in 2023-24 DPS1 trialled the integration of UCL's Academic Communication Centre (ACC) across all departments. Analysis of the impact will be reported

in a separate publication. The hope is that if this strategy proves to be successful in DPS1, it can be rolled out to across all year groups. The improvement in language skills, paired with the ability to practice presentations repeatedly with the *GoReact* tool should significantly help to improve presentation skills as students' progress through their studies.

Writing Skills

The ability to write well is one of the most coveted skills by employers in engineering as reported in the literature review, yet it is the one that has proved most difficult to see significant advancements in engineering education (Narayanan, 2010). Studies have shown that one of the factors contributing to this relates to students' reluctance to devote time and effort to writing (Narayanan, 2005). This has been observed by staff in this study who expressed the challenges in motivating students to write:

> "*So my second years they don't believe in writing. It's literally the truth. They hate writing. They hate writing reports, and I wish that there was more emphasis. They have to know that when you go into a company, they have documentation, you have to write reports."* (Dean, 2nd year)

Research has shown this attitude to continue into latter years of study, particularly with the pressures of larger pieces of writing such as dissertations carrying higher weightings at the end of degree programmes (Jenkins, Jordan and Weiland, 1993). As Dannels, 2002 reports, it is important to recognise that there are differences in expectations of writing motivation between working engineers and student engineers, however engineering employers have also reported similar observations, particularly from early-career engineers, further highlighting the importance of continued efforts in the area of changing students' perception on the importance of such skills (Yong and Ashman, 2019).

Staff in this study were able to identify specific areas of writing that appear to be challenging for students, regardless of their year of study, and there were commonalities between different departments:

> "*I find that students want to report everything and they don't feel comfortable omitting any information and they feel like because they've done work on something they have to show it.*" (Nelson, 4th year)

> "*I think one of the things that they don't know how to do in their third year when they arrive there is basic report outlining you know what's important to say in each part*." (Ted, 4th year)

> "*One is that they are very uncomfortable with writing short reports. This is condensing their writing into something that is the real stuff and not using a lot of space*." (Lucy, 4th year)

A four-year study carried out by Gunn, 2013 to identify the specific challenges faced by advanced engineering students in communicating their work via writing observed similar findings to those expressed by the staff in this study. The findings of the study suggested that the main areas of concern were disorganisation in idea expression and poor writing of introductions and conclusions. When asked to produce a summary of written work (an activity frequently performed in employment), students found it challenging to condense

information, select the most relevant content, contextualise information at the beginning and the end as well as general structure. Comparable studies were carried out by Wren, 2018 relating to quality of written communication, particularly students' confusion between what belongs in the introduction and conclusion sections as well as differentiating between description and critical analysis.

Conrad, 2017 performed a recent study that compared writing performance between engineering students and it was shown that quite a few students had less accurate word choice, issues with report structures and as well as arguably more concerning issues related to plagiarism and grammar. This was also a concern raised by staff in this study:

> "*I think you know there's stuff around paraphrasing, for example, where students get that wrong and they get into a lot of trouble with Turnitin, and they just don't understand it*." (Harry, 2nd year)

> "*I sometimes teach them how to punctuate and even in year 2 I teach them this, it becomes hard to teach them something worthwhile, it becomes hard when they don't have the right foundations and they have that crutch … they don't necessarily develop individual good writing skills and referencing.*" (Tim, 2nd year)

There are undue pressures on engineering educators to incorporate the teaching of foundational writing into the engineering curriculum, and whilst efforts are being made to do so, it is recognised that support from writing experts is needed (Thakur, Kaur and Thakur, 2013). A qualitative study conducted by Mokgwathi and Otlhomile, 2015 collected feedback on the efficacy of the recently implemented two-year foundational technical writing (TW) course (a course all engineering students in the Botswana International University of Science and Technology are required to take) from the points of view of engineering lecturers. The TW course is taught by TW specialists and is designed to prepare engineering students to write various types of engineering documentation to a high standard, covering areas related to grammar and punctuation, writing organisation and technical arguments, critical thinking in academic writing and information literacy.

Engineering lecturers fed back that the course had provided significant improvement in students' writing skills, with one participant stating, "*I do not have a lot of work correcting grammar when I mark their scripts.*" A number of lecturers also reported on the significant reduction in plagiarism, improvements in research skills and referencing, along with a better understanding of writing structure. One area that was still noticeably problematic was related to difficulties in condensing large amounts of text into summaries, which was not an explicit learning outcome on the TW course.

To address similar concerns expressed by staff in this study, as mentioned previously DPS1 has trialled integration of UCL's Academic Communication Centre (ACC) with the module and analysis of its efficacy will be evaluated and published separately. Whilst it would be unfeasible, given the structure of degree programmes at UCL Engineering, to include something as comprehensive as reported in Botswana International University of Science and Technology, a similar concept will be applied via the use of academic writing experts collaborating with engineering educators, with the explicit addition of summary writing as a learning outcome. Students will work with ACC staff using specific writing assignments from DPS1. As they work on the DPS1 assignment, they will receive regular feedback from ACC staff, helping them to improve their writing with each iteration and apply the same

concepts to other assignments on their degree programme. The anticipated outcome is a significant improvement in lab report writing, referencing, plagiarism and summary writing. Student and staff feedback on its efficacy will be collected in annual module evaluation surveys.

Summary and Conclusion

The findings discussed in the previous section indicate that from the perspective of the staff involved in the study across the six departments, there are a number of commendations as a result of the introduction of skills-based teaching on DPS1. These include the general concurrence that presentation skills are well developed, and the transfer of these skills are seen as students progress through their studies. Also included in the commendations is the improved student perception of the IEP and skills-based teaching as they get towards the end of their degree programme (to be discussed further in future publication).

With that said, staff expressed concerns over the continued confidence issues that students face in presentations. To help address issues with confidence, DPS1 have introdroduced the use of the online tool *GoReact*, where students are able to record themselves presenting, watch back their presentation repetitively, and get peer and staff feedback. Similar tools have been used successfully in literature, so it is anticipated that similar results will be seen on DPS1. A further improvement in relation to teamwork skills involved adequately assessing conflict resolution. Whilst many studies recognise that it is a challenging aspect to assess directly, recommendations such as the roll out of the IPAC tool, combined with systematic reflection (as used in employment interviews) may help to address this. Staff mainly expressed concerns over students' inability to write concisely i.e. identifying what is important to include and what can be left out, as well as some basic writing skills due to language barriers. To address this, DPS1 have trialled a collaboration with UCL's ACC. Literature has reported on improvements in student's writing skills as a result of collaborative efforts between staff with expertise in writing and engineering educations. It is anticipated that similar results will be seen upon applying this strategy on DPS1.

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