Improving students' critical thinking and communication skills

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ABSTRACT

University engineering faculties, professional engineering institutions and industry increasingly recognize that higher education should support students to develop key professional skills such as critical thinking and communication skills. This paper examines three activities aimed at teaching these skills, i.e. practical open-ended group activities; discussion with experts or as experts; and peer assessment. These methods were assessed in terms of student and staff opinions, but also practicality. Our research indicates that it is beneficial to integrate and balance these three types of activities within engineering degrees as they complement each other. Our findings and conclusions can be applicable to any engineering degree, whether the aim is to incorporate the teaching of these skills in a small activity within a module or a full programme of studies.

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Conference Key Areas: Engineering skills, Continuing Engineering Education and Lifelong Learning, Curriculum Development.

Keywords: critical thinking, engineering skills, peer assessment, research-based education.

INTRODUCTION

Engineering employers expect graduates to have a good knowledge of their field of study, as well as workplace skills such as critical thinking and communication skills [1,2]. Universities and professional engineering institutions increasingly recognize this need and incorporate the development and assessment of professional skills within their accredited curricula [3-6]. In general, practitioners acknowledge that these skills must be built over time, and therefore must be integrated throughout the programme of study. Different methods are used in the literature. This paper focuses on 3 generic overarching teaching methods, i.e. (i) open-ended practical activities and research based education, (ii) discussions with a range of experts and sectors, and (iii) critically analysing other students' work with peer assessment.

Open-ended practical activities and research based education provide students with "real-life working scenarios" where they apply and reinforce their technical knowledge, critical thinking and problem solving skills, as well as communication and team work. Employers are looking for graduates with this type of experience [2]. Students often find these activities challenging but often engage and learn with them.

Engineering students benefit from interacting with a range of audiences and experts, preparing them to communicate effectively in a range of roles relevant to industry, such as speaking with clients, experts, peers, etc. [1,2]. Furthermore, dialog with experts within and beyond academia challenge the students and supports their critical thinking development; while taking the expert role and engaging with less technical audiences -e.g. peers and junior students- develops their confidence and knowledge further [7].

Finally, peer assessment is increasingly applied in higher education because it enhances students' learning and development of critical skills [8,9] among other benefits [10,11]. However, there are concerns that students may not engage with peer marking [9,12] and may not trust peers to make fair judgements [12]. This can be mitigated by using the 360-degrees peer-assessment method (360PA) where students are assessed in part on the quality of feedback that they provide [13]. The use of peer assessment gives the students an opportunity to learn how to express feedback in a constructive and tactful way.

This paper describes and compares these three different educational activities to foster the development of critical thinking and communication skills. Evidence was obtained from teacher observations, discussion with teachers and student, and anonymous questionnaires filled out by students. Some examples of implementation and final recommendations to practitioners are provided.

1 PROJECT METHOD

1.1 Overview of activities incorporated within the programme

A range of "non-traditional" activities were incorporated within the BEng Biomedical Engineering programme (BME) (https://goo.gl/pfMTPa), part of the Integrated Engineering Program at UCL, UK. These complement traditional lectures, tutorial sessions, and traditional practical sessions often incorporated within modules where students carry out a set of defined instructions, e.g. an experiment, or certain routines in a piece of software. We investigate activities grouped into three general categories:

(A) Open-ended group activities: These are long practical activities where students are presented with a problem that they need to solve, or a research question that they need to investigate, but are given freedom in what the end-product should be or how to reach it, hence 'open-ended'.

We examine various instances of these open-ended group activities: (i) six so-called 'scenarios', which are one intensive full week activity covering a range of topics such as programming, electronics, mechanics, design, etc; (ii) research activities, typically spanning up to a term, where each group defines and solves its own research question, e.g. first year students investigate the mechanical properties of a material using the Instron E3000 [14], and present their results via poster in a conference-type setting; (iii) large design group project in the 3rd year.

(B) Discussion with experts or as experts: Meaningful learning requires that students are not passive receivers of information. Academic discussion with lecturers is a common practice in Higher Education and an excellent way of challenging students, widening and reinforcing their knowledge. Additional approaches investigated in this paper, are: (i) frequent exposure of students to non-academic experts, e.g. from industry or the health system including visit and shadowing clinicians at hospitals, and patients; (ii) students present and discuss their results to a range of experts in the field as part of the assessment; (iii) students are encouraged to engage with younger students and act as experts, e.g. supporting the teaching in a given practical, or discussing and giving formative feedback to 1st year students.

(C) Peer assessment (PA): PA is used in many modules across the degree, in a range of assignments such as reports of experimental work, video, a section of the final year project dissertation, presentations, and mathematical assignments.

1.2 Assessment of impact by students

Third year students were invited to complete an anonymous questionnaire. This questionnaire looks at how confident students are with respect to 4 specific skills, defined as S1 to S4 below, if they developed such skills since the start of their degree, and how the types of activity A, B and C (as defined in section 1.1) contributed to such development. All questions have a 5-point scale. Student's quotes are also provided. The skills investigated were:

- S1: Critical thinking
- S2: Communication with a range of audiences and different situations
- S3: Critically analyse someone else's work
- S4: Constructing feedback for peers or junior students.

1.3 Assessment of impact by staff

Similarly, interviews were conducted with members of staff to investigate the effect of activities A, B, C on the development of students' S1-S4 skills. Those staff members selected had contact with the students at different years during their degree. They were asked the following questions:

- Since the students started their degree, have you observed an improvement in their abilities with regard to S1, S2, S3 and S4? :

- If so, how did you observe these changes?
- What do you think has caused these changes?
- Have students changed their approach to scenarios?

1.4 Other factors

Also considered in the assessment is staff time and resources needed.

2 RESULTS

Students' feedback via questionnaires is presented in *Table 1*. A sample of students and staff point of view on these three activities is given in *Table 2* and *3* respectively.

Table 1. Third year students' responses to questionnaire (N=9, 90% of the class). Scale: 1- not at all, 2- not very, 3- fairly, 4- significantly, 5-very. Mean (SD)

	S1	**S2**	**S3**	**S4**
Current confidence in your ability?	3.9 (0.7)	3.9 (0.7)	3.7 (0.5)	3.9 (0.6)
Has it developed during your degree?	**4.4 (0.7)**	**4.1 (1.0)**	**4.2 (0.7)**	**4.1 (0.8)**
Has this type of activity helped you to develop it? (A) Open-ended group activities	**4.1 (1.1)**	**4.7 (0.5)**	3.7 (1.1)	**4.0 (0.7)**
(B) Discussion with experts or as experts	**4.4 (0.5)**	**4.3 (0.9)**	3.2 (1.3)	3.7 (0.9)
(C) Peer dialog and peer assessment	3.1 (1.3)	3.0 (1.1)	**4.0 (0.7)**	**4.0 (0.7)**

Table 2. Quotes from students (representative sample)

Student 1: *"Open ended activities have helped me improve my skills in communicating with team members and motivating each other to work well together to produce a good piece of work, towards a strict deadline. It's really helpful as it helps you understand what it's like to work in a team environment, especially for working in companies in the future.* *Discussion with experts helped me to improve my communication skills also, especially learning to be empathetic towards patients and what examiners want.* *Peer assessment helped me learn how to critically analyse someone else's work and ensure I give good feedback, as well at utilising the feedback I was given."*
Student 2: *"Discussion with experts: Good for constructing feedback as you learn the opinion of people with experience in a particular area, and you can apply this to your feedback for others. […]* *PA: Gives you more time to think about how to word your feedback, but quite frustrating if those who are giving you feedback do not put effort into it."*
Student 3: *"Being pushed to engage in the activities [A, B, C] meant there was a need to refine my skills in these areas."*
Student 4: *"[…] I think my critical thinking was developed most with the expert discussions as they would ask questions that make you think deeper about the topic, which I found challenging but good.[…]"*
Student 5: *"Open-ended group activities such as scenarios have greatly improved my critical thinking skills to solve new problems in a creative way. They have also improved my communication skills when working in a team with colleagues, lecturers and area experts. […]*

PA activities have improved my ability to construct feedback and shows you how other people think which can improve the way you critically think yourself.   *[Recommendations for the future] Continue to combine the talks with experts with the open-ended group activities. Peer assessment is helpful but is also time consuming […]. All these activities [A, B, C] are important and should be incorporated in the Biomedical degree."*

Table 3. Quotes from members of staff (representative sample)

EH, Laboratory Technician, supports students during practical activities and scenarios in years 1 to 3:   *"Yes, [I have observed an improvement on the students' abilities to S1 and S2].*   *S1: Students were made to think critically of their strategy in Scenario 2. [At the end] the students were asked to contribute one thing they had learnt […], some students were incredibly reflective realising their downfalls in planning at the beginning led to a poorly constructed investigation.*   *S2: Throughout scenarios students have needed to present their work to scenario leaders and experts, […] work as teams and communicate their ideas effectively. I have seen students greatly improve their ability to work in a team; some students start the first year scenarios afraid to speak their opinions to their team mates and are more confident in doing so by the scenarios in the second year.*   *[In] scenario 6, students get to experience contact with a 'patient' to test their device, this gives them chance to learn a vital skill in communicating at a completely different level to the common student- teacher interactions […].*   *In general: For some students failure has been the predecessor for change, learning from mistakes of previous scenarios.[…] By the second year students become much more familiar with the concept of scenarios and how to deal with them, they are happier with the freedom to plan and construct their own ideas. They do not ask for help as much, they come up with ideas within their groups and do not need constant affirmation."*
JG, Principal Teaching Fellow, lecturer in year 1 and lead of 2 scenarios: *"S1: It's difficult to say as I see just a snapshot of them. However I believe that the students' critical thinking improves during the week of the [3rd] scenario when they have to actively problem solve in order to get to the end point.*   *S2: Communication definitely improves throughout. First year students are usually quite nervous about presenting, but by the time they get to the [5th] scenario, they are almost all confident about presenting to what is actually quite a scary audience.*   *S3: Again, I've not seen the students analyse much of other's work – just really in Dragons den. This year, a couple of groups were able to comment on and consider whether or not they actually believed that the technologies given to them would be good in the market place. It takes a certain amount of confidence to speak up when presented with an academics' research work.*   *S4: I've not had the opportunity to see this in action.*   *In general: Giving them opportunities to attempt all these skills regularly, combined with a mixture of feedback and constructive praise [is what has caused this development on the students]."*

3 DISCUSSION

Engineering students and staff (including the authors of this paper) believe in general that the types of activities under study (A, B, C) did help to develop critical thinking and communication skills (S1-S4) of engineering students. A comparison between the 3 types of proposed activities is summarized in *Table 4*, and discussed below.

Type A activity, i.e. open-ended practical activities, seems to give the engineering students the chance to use - and the need to develop - the full range of skills (votes range 3.7-4.7/5) in general, and are recommended by staff for the training/learning they provide. According to the student questionnaire, S3 (critically analyse someone else's work) is perhaps the skill accomplished to the least degree with this activity, demonstrating that although students are working and assessed in groups, they are still not ready/inclined to analyse and criticize the work of their peers. But overall, the students enjoy and appreciate open-ended group activities. For instance, during one open-end research activity the 1st year students (N=23) claimed that they learnt a lot (mean vote = 3.8/4), and that it was a valuable learning experience towards their future (mean vote = 4.0/4). However, setting up, resourcing and running this type of activities can be highly time-consuming and costly.

Type B activity, i.e. discussion with or as experts, is very popular among students, getting a high mean score for S1 (4.4/5) and S2 (4.3/5). Students learn how to critically analyze and interpret information by discussing with experts (lecturers, researchers, industry, medical doctors), and learn to communicate with different audiences (including non-technical people e.g. patients). Part of this is done within classes and support sessions, which it is the least time-consuming and most economical option. However it is also good for the students to have the chance to share their thoughts with experts while working on engineering (open-ended) projects. These personal discussions are of high value as the student has a good understanding of the project at hand, allowing the questions/discussions to be deeper. If organized into timetabled sessions, these one-to-one discussions are feasible. However, the total number of staff hours increases with the class size.

Type C activity, i.e. peer dialog and peer assessment, seem to address the development of skills S3 and S4 according to the students, with scores of 4.0/5 in both cases. Many students see and comment on the benefits of this activity; however some are still skeptical and might not engage with it as much as they should because they consider it as something extra rather than part of the assignment. The use of the *360 degrees peer assessment method* partially solves this problem, while allowing staff to measure and assess the ability of students to construct feedback. It requires the students to critically analyze the work of their peers and engage with the feedback received – both of which they might not do otherwise even if working in groups! This type of activity is the least sensitive to class size, in fact allowing a large class to get feedback on their work in a relative small amount of time with minimal staff involvement and resources. Staff using this 360PA method thought that the feedback provided by the students was thoughtful, of good quality, and more extensive than that provided by staff [15]. Activities type B and C seem to be complementary to one another.

By the end of the third year of the programme, students were still not quite confident of their critical thinking and communication skills (S1-S4) with scores between 3.7-3.9/5. This is surprising, considering that activities (A, B, C) have been integrated across the programme in part with those aims, but reinforces the need to support the students in the developing of these skills as to be ready for their professional lives. However, it seems that the proposed activities work, with students acknowledging that they have significantly developed skills S1-S4 during their degree (average ranging

4.1-4.4/5). Students' preference and perceived benefits among these activities vary, further supporting that they are used in combination.

Table 4. Comparison of the proposed types of activities

Activity type	Students	Staff	Resources
(A) Open-ended group activities	High engaging, significantly develops skills S1, S2 and S4.	Develops S1 & S2, might help S3-S4 but no evidence. Very useful as training for engineering.	Highly demanding: space, equipment, staff-time for preparation and support
(B) Discussion with experts or as experts	Very useful for S1 and S2	Can be more easily incorporated in different parts of a module. Useful. Students might engage differently.	Staff time: medium No cost or lab requirements.
(C) Peer dialog and peer assessment	Significantly useful for S3 and S4. Not all students like it.	S3 and S4 can be assessed. Prompt and good quality feedback, more detailed than staff can provide.	Staff time: low No cost or lab requirements. Easily scalable with class size.

4 CONCLUSION

This research looked at 3 generic types of activities, and seem to be in agreement with other studies in the literature that claim the benefits of using active learning methods such as project-based learning [3, 5] (type of activity A) and outfacing assessment to High School students [6] (a form of activity B). It also covers the evaluation of peer assessment (type of activity C) that was identified by Llorens [3] as something that had to be investigated.

Our practice suggests that it is beneficial to integrate in the programme a range of practical open-ended and research-based activities, dialog with a variety of experts and sectors, and the use of peer assessment for various elements. A balance between these options is desirable, as the first two are demanding in terms of staff-time and resources, while peer assessment can be more scalable. The combination is able to cover the development of the studied skills, i.e. critical thinking and communication skills. Our approach is relevant to teaching critical skills, either in a small activity within a module or a full programme of studies.

This research should continue to proof its reliability, involving larger classes and perhaps looking at student and staff perception after the 1st and 2nd year of the degree.

5 ACKNOWLEDGMENTS

The authors would like to thank to the students and staff members (Miss Eve Hatten, and Dr Jennifer Griffiths) who provided feedback and quotes for this paper.

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