INTRODUCTION TO INDUSTRIAL DESIGN AND PRODUCT CASE STUDIES

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ABSTRACT

This paper describes the practical elements included in the first term of a second-year engineering module which was developed in alignment with CDIO standards. The students were assigned into teams based on their course of study (i.e. electronics, biomedical, and sports engineering). Each team would be free to choose, research, and evaluate three products with some relevance to their field. Aspects such as technology, regulations and user reviews would have to be considered within the analysis. The scientific principles involved in the products would have to be explained in reasonable depth and aspects such as product end-of-life management (sustainability) also mentioned. Multiple sources would have to be used such as scientific articles, product specifications, regulations, and online reviews. The students would have to use available resources without necessarily having the actual physical product at hand. Once the teams had gained insight on the products they would have to either choose one of the products to improve, or decide to design a new product, (relevant to their discipline). The teams would have to produce a report and a demonstrator of their designs by the end of term. The demonstrator would have to be a physical representation with some functionality that can effectively communicate the proposed concept. The students were expected to use the tools and experience gained during previous and prerequisite modules, for designing and prototyping. The report was also expected to contain references to the indicative reading. The module would be an opportunity to build upon previous knowledge obtained through both, core and specialized modules. Additionally, a research element was included both in terms of the students looking into the cutting-edge technologies of their subject but also in trying to push those boundaries. This study aims at describing the module rationale, and reflecting upon inclusivity, and pedagogical effectiveness.

KEYWORDS

Group projects, innovation, industrial design, Standards: 1, 2, 3, 5, 7, 8

INTRODUCTION

In 2017 a new engineering department was established at Nottingham Trent University (NTU). The first cohort included three courses i.e. biomedical, electronic and sport engineering. The department has since been developing to foster an inclusive ethos and a modern approach that corresponds to the current professional needs and in alignment to CDIO standards. In that context the first term of a second-year module was developed. The term grade would account for 50% of the module grade. The module was named ‘Industrial design and product case studies’ and was taken by all engineering courses (35 students in the first cohort). The cohort included both native and international students of various educational backgrounds (e.g. international, more technically or theoretically focused) and with a multitude of talents, areas for improvement and strengths. This study aims at describing the module design rationale, and reflecting upon the design impact in inclusivity, and pedagogical effectiveness.

The module learning outcomes included:

- Source industry relevant information, some from the scientific literature, to inform the design and manufacture of engineering products/systems.
- Review and evaluate information related to end-user needs, materials and component properties, industry standards and methods of fabrication, including knowledge of industrial manufacturing processes, economic viability and environmental concerns.
- Formulate and manufacture engineering solutions to overcome discipline specific engineering problems using standard engineering solutions.
- Utilize digital methods in the design and fabrication of engineering products.

The aim was for the module to fulfill the desired learning outcomes, in a way that would be representative of a working environment, cultivate creativity, and enable all students to utilize and hone their strengths while developing in new areas. This would also adhere to the concept of constructive alignment as the purpose of each task would be clear to the students (Biggs, 2011). As the module name implies the students would have to explore case studies of industrial design. Due to the department being new, that was the first time that the specific module would run at NTU. It is not uncommon in such modules to be taught in a traditional lecture manner whereby the educator delivers knowledge through a lecture format and then an exam is constructed to test the retention and understanding of that information. Case studies might have been the topic of lectures perhaps covering one example per session. Nevertheless, the purely passive demonstration model is not necessarily the most effective in sciences that include practical elements. For example, (Crouch et al., 2004) found that physics demonstrations to pre-medical students had no significant effect on correct answers.

In 1996 MIT was evaluating its curriculum and in collaboration with Boeing constructed a list of desirable attributes of engineering graduates. This to some extent contradicted the weight that some schools would assign to the ‘soft skills’ in comparison to that of industry (McMasters & Matsch, 1996). With that in mind, the module was designed with an approach of guided and supervised self-learning based in lab sessions rather than lectures, and closer to a Humboltian model of academic education. The main bulk of contact time would be spent working in teams and in the laboratory with the support of 3 lecturers and technical staff.

(Prince, 2004) suggested that active learning is an effective method and in addition to the team element (Johnson & Johnson, 2008) may enhance meaning extraction. Additionally, it is argued that including social interaction can be an effective way of learning (Ashwin et al., 2015). A significant aspect would also be the contribution of multiple members of staff as (Thomas et al., 2015) emphasise the importance of staff support and environment to facilitate effective self-learning. The effectiveness of the method would be evaluated by student feedback through anonymized questionnaire forms, student grades, moderation by colleagues, and fellow staff feedback that would be invited to participate at a specific phase of the module.

Below the module design is described in more detail and considerations regarding student achievement are discussed. Student achievement is addressed in both the specific sense of grades but also in the general sense of being equipped with a range of skills that are conducive to professional success. The variety in terms of student backgrounds, talents and skills might correspond to that different students have different needs in terms of areas they need to develop. The module, would provide with a sufficient variety of tasks so that students could both shine through their talents and also develop needed skills.

MODULE DESCRIPTION

The students were assigned into teams based on their course of study (i.e., electronics, biomedical, and sports engineering). Having taught the cohort in the previous year and considering its small size, I already knew the students. Some consideration was taken in forming the teams based on general student performance and engagement during the previous year. Although the performance of previous years is not necessarily deterministic of future performance, the aim was to try and ensure a reasonable balance between teams. Each team would be free to choose, research, and evaluate three products with some relevance to their field. Aspects such as technology, regulations and user reviews would have to be considered within the analysis. The scientific principles involved in the products would have to be explained in reasonable depth and aspects such as product end-of-life management (sustainability) also mentioned. Multiple sources would have to be used such as scientific articles, product specifications, regulations and online reviews. The students would have to use available resources without necessarily having the actual physical product at hand.

Once the teams had gained insight on the products they would have to either choose one of the products to improve, in at least one aspect (e.g. function, cost, sustainability, manufacturing), or decide to fully design a product of their own, (relevant to their discipline). The teams would have to produce a report (including CAD design in Fusion) and a physical demonstrator based on their design by the end of term. The demonstrator would have to be a physical representation with some functionality that could effectively communicate the proposed concept. A full functioning prototype would be preferable and appreciated, however it might not have been feasible given the available time. The students were expected to use the tools and experience gained during previous and prerequisite modules, for designing and prototyping. The report was also expected to contain references to the indicative reading. The module would be an opportunity to build upon previous knowledge obtained through both, core and specialized modules (Fry et al., 2008). Additionally, a research element was included both in terms of the students looking into the cutting-edge technologies of their subject but also in trying to push those boundaries (Barnett, 2005).

The length of the analysis part of the report was restricted to 3 pages per product, however equations, figures and appendices were excluded from that allowance. The aim was to force the students into evaluating and distilling the vast amount of information about the products so that to reflect and include only the relevant and important parts.

The projects were structured in a way often found in relevant industries which includes 'gateways' or checkpoints and a suggested timeframe. Gateways were non-graded opportunities for feedback and guidance on the laboratory methods and findings during the laboratory sessions. There would be 3 gateways structured as semiformal assessments of progress. Examiners would evaluate the required deliverables up to the point of each gateway in order to allow for the team to proceed to the next stages. The deliverable elements during the gateways were necessary parts for the final assessment. It is argued in (Gibbs, 1999) that assessment is a main element in student engagement and that it can be used strategically.

The gateways were in addition to the regular contact with the students during the laboratory sessions. The three gateways and deliverables, with the suggested timeframe were:

1. Analysis of existing products (recommended 4 weeks)
2. Choice of product and improvements or general idea for new design (recommended 2 weeks after gateway 1)
3. Detailed development of new designs and presentation with demonstrator (recommended 5 weeks after gateway 2). The presentations were held at the end of the project and teams were expected to highlight the main points of their reports and showcase their demonstrator within 20 min scheduled slots. An open trade show styled exhibition event would follow the presentations.

Gateway 3 would be open to other members of staff who would like to attend the presentations. After the presentations, a small trade show formatted exhibition would follow. Several colleagues attended the event and gave feedback to the students. The aim of this would be to also enable students to learn by explaining (Ploetzner et al., 1999). The event was scheduled near the end of term and a bit before the deadline for the report submissions so that students could incorporate the feedback or clarify aspects of their reports.

Technical support and three lecturers were assigned for the regular lab sessions. The tutors would monitor the methodology, team dynamic, and progress of each team. Discussions and recommendations were regular. During gateways, all tutors would be involved in giving feedback, and teams would either fail or pass to the next stage. If the teams failed a gateway, then specific guidelines and a timeframe would be given for the corrections.

A small budget was secured through the engineering department teaching funds that was aimed to cover parts for the practical development of the demonstrator. Teams had a deadline to submit their "shopping" list and apply for approval within a limited allowance. Technical staff was also involved in evaluating and consulting the students with regards to existing resources, alternatives, procuring and assembling the relevant parts.

Assessment was subject to a two-stage moderation process, i.e. one before and one after the assessment. Firstly, any details related to the assessment (e.g. clarity of information and the assessment criteria) were considered by a member of staff outside of the module team. Secondly, the awarded grades were considered by both the module team and an additional member of staff, to check for consistency and fairness across the cohort for the submitted work.

Within the report a section was dedicated to methods in which the students would have to describe the methods that were followed during the different stages of the project as well as roughly outline the parts in which each member of the team was involved.

Additionally, peer review forms would be circulated after the report submission deadline. The peer review forms were optional and confidential. The forms were structured in two sections. The students would either fill the first section in which according to their opinion all members of the team contributed about equally to the project, or the second section in which they would rate each member of their team (including their self) between 0-5, were 0 would be virtually no contribution or absence, 3 about average contribution in relation to all members, and 5 contributing significantly more than other members of the team. Additionally in this section, the students would have to state the parts of the project in which each member contributed.

No action in terms of grade differentiation would be considered in cases of minor differences of perceived contribution. The forms would be actionable only in the case of multiple members agreeing in someone’s extremely low contribution. Peer assessment information would also be checked with engagement and attendance. The aim was for the grades to be capped by the grade of the collective effort and then if necessary, to equitably differentiate based on significant discrepancies in contribution.

DISCUSSION

The students were assigned into 7 teams and aspects of team working were addressed. The importance of establishing an environment where people can comfortably contribute ideas was emphasized. Arguably, there is a synergistic potential in well-functioning teams. The aim was to encourage engagement and the development of a sense of ownership for the project, from the whole team, by removing potential barriers to engagement and contribution. All teams worked reasonably well and produced great results (Figure 1). On occasion tensions might arise between team members and particularly around deadlines. This is not uncommon in professional life. It is important for students to learn how to manage such situations (Patterson, 2002) and resolve them as educated adults. Engineers often have to work in teams with colleagues that are assigned rather than chosen. A variety of personalities, working styles specialties may be clustered with the purpose of achieving a specific goal. The module offered a controlled environment with limited professional risk and controlled pressure so that the students could develop some of the necessary skills for collaborating with multiple people under the pressure of deadlines and limited resources. Confidential peer assessment forms were circulated. No actionable peer assessment resulted from the process.

The student feedback from anonymized questionnaires regarding the module, was very positive. Through the comments, students had particularly enjoyed the practical aspects of the module and found it to cater to their interests. The connection between the theoretical parts (even of other modules) and the practical side of this module became apparent especially during the analysis of existing products and the improved design.

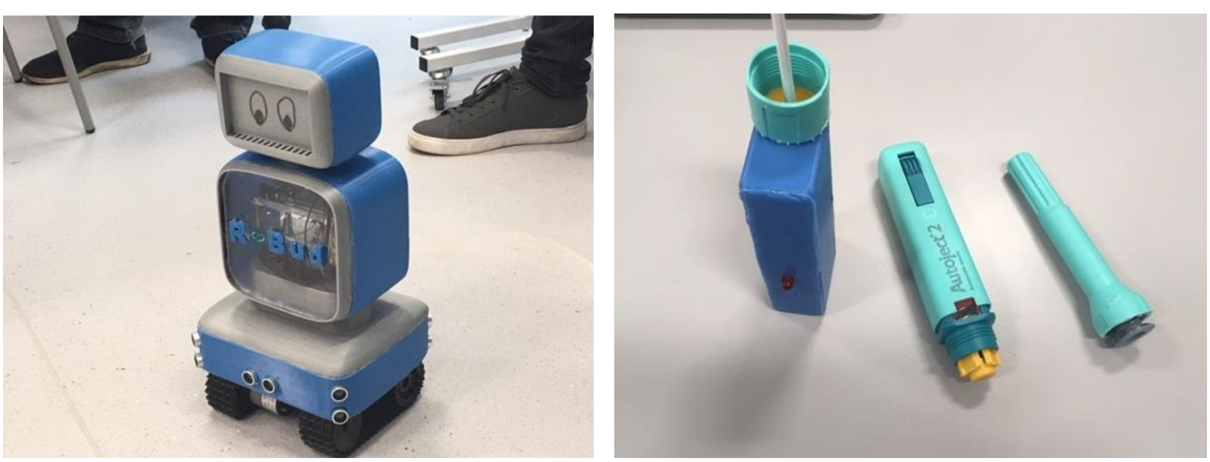

Figure 1. Examples of student demonstrators (left) a remotely controlled robot from a phone application with an additional option for autonomous random movement and with obstacle avoidance, (right) a commercially available injection delivery device that was modified by students to include an audio-visual signal upon drug delivery completion. Both demonstrators performed well and were parts to more general concepts that the students were proposing. Image’s courtesy of Edward-Joseph Cefai, Erfan Sakhi, Shanice Ria Tarbert, Sophie Harrison (left) and Agho Omoragbon Ederhumnwu,

Jefferies Thomas, Lawrence Clayton, Lee Anthony, Peverill-Jones Jacob, Rodney Munashe Moses (right).

The multifaceted nature of the projects included a variety of tasks to be distributed amongst the team members. Both theoretical and practical tasks were required for the completion of the projects. This would allow students to utilize different strengths they might have (e.g., as a result of a different educational background) or be encouraged to push themselves outside their comfort zones and try to develop skills they might be lacking (e.g., written English, presentation skills etc.). It was stipulated by tutors that this would be the opportunity to try and get feedback e.g., gateways on different tasks in order to develop new or hone existing skills. Multifaceted teaching is supported against the previously thought learning styles model (Husmann & O'Loughlin, 2019) and perhaps adds to an inclusive framework.

Coursework was moderated according to an internal review system. Although grades is not necessarily the most accurate measure of teaching effectiveness, the students achieved higher grades than the general average and regardless of educational background. None of the engaged students failed the module. Attendance and engagement was at very good levels.

The staff that attended the exhibition event engaged with the students, and prompted them with regards to their work. Colleagues enjoyed the event and shared positive comments. Some of the demonstrator prototypes didn't fully work due to bugs and system glitches which would be expected given the short time scale. However, the students managed to show most of the main features and concepts they had developed.

The projects included tasks that could be performed either during the lab session or independently and then integrated in the project. Several students might need to work in jobs outside the University and in parallel to their studies, and perhaps they would miss some or part of the sessions. The module format was designed to have some tolerance to individual working habits and scheduling needs and therefore being more inclusive.

Students would help each other across teams based on their course e.g. electronics students helping other teams with the electronic aspects of their demonstrator. There wasn't any deliberate competitive element in the design of the module. Peer interactions were encouraged i.e. discussion and communication between teams, as (Brame & Director, 2016) also suggests that active learning that includes peer interactions may promote the development of 'extended and accurate mental models'. Whilst fellow students from other teams were allowed to assist in elements of the development e.g., debugging, tutors monitored the process to ensure that there was no outsourcing. The development of the demonstrator was only a part of the assessed work however it seemed that it was perhaps the most exciting.

This was generally a very engaging and exciting module both for students but also for staff. Excitement can be a positive element in module development (Bonwell & Eison, 1991). However, this was very resource intensive in terms of staff time and ordered parts cost. Modules including prototyping and development tend to be more costly than theoretical modules. This might become an issue in terms of the scalability of the module. Part of the module success was the staff to student ratio and the ability to dedicate personalised attention. The staff was familiar with the state and progress of the teams. This would allow for staff to anticipate and catch any problems early in order to advise students in applying corrective actions. Significantly, higher student numbers might dilute the amount of individual attention and the resulting student experience might vary.

CONCLUSION

The design of a practical element within an engineering curriculum was described above. The aim was to design a module with student achievement in mind and using elements that would enhance an inclusive frame. Arguably, inclusive and practical methods can be professionally relevant and educationally beneficial. Ultimately, achievement and inclusivity is not just about achieving good grades but achieving in career goals and realizing individual potential. A well-structured and implemented curriculum would provide students with the tools for both. I believe the designed module took deliberate and informed guidance from both literature and industry in order to form an inclusive environment for students to develop and perform.

Challenges in equitable marking, ensuring smooth collaboration between students and effectively scaling the module to higher student numbers, potentially by also using more online tools and resources, would be consideration topics for the future. Feedback and ideas from students and colleagues will continue to inform future planning and module design.

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Dr Siegkas is a senior lecturer at the NTU Department of Engineering and has been involved in teaching Innovation and Engineering Solutions, Industrial Design and Product case Studies, Sport Technology, Mechanical Engineering in Sport, Optimising Sports Equipment. Research interests include solid mechanics and engineered materials, with applications in 3D printing, traumatic brain injury, biocompatible implants, aviation safety and others.

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