STRENGTHENING CDIO IN B.ENG. FINAL PROJECTS WITH AN INDUSTRY ROADMAP

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ABSTRACT

The increasing demands from industry present students undertaking their internships and final projects with a correspondingly steepening learning curve. Upon completion of internships and final projects, when the student may leave the company, the true potential value of the activities is often not fully realized due to the limited exchange of information between the company, the university and the student. This paper presents a roadmap for improving knowledge dissemination and value creation for both university and industry along with developing the engineering competencies of the student. Regular evaluations of the design-build experiences with the students, industry and academic supervisors (CDIO Standard 5) are essential elements in the process along with the revision of outcomes according to industry stakeholders' needs (CDIO Standard 2). The process establishes a continuous flow of students undertaking internships and subsequent final projects. An overlap of students, i.e. an intern along with a final project student, combined with strategic meetings ensures knowledge transfer and continued value creation. Furthermore, upon completion of the final project, the student is encouraged to propose a technical profile status report for development efforts for the coming years for the company, including the most important technical elements to support this. This proposal is also used as reference material for the subsequent internship and/or final project. The roadmap has been successfully applied for several semesters within a company producing polymer products for the medical industry and is further detailed in the paper. Students who have undertaken their industrial placement and B.Eng. final project following the roadmap have been required to communicate their findings and conclusions to their peers and supervisors to a greater extent than previously which has strengthened the inherently integrated learning experience (Standard 7).

KEYWORDS

University-industry collaboration, R&D learning environment, B.Eng. final projects, internship, Standards 2, 5, 7, 9

INTRODUCTION

The Centre for Bachelor of Engineering Studies at the Technical University of Denmark (DTU Diplom) has implemented the CDIO framework and standards in all B.Eng. programs offered since 2008. Close collaboration with industry has always been an essential element in providing the design-implement experiences (Standard 5) and the integrated learning

experiences (Standard 7). The B.Eng. programs consist of seven semesters (3.5 years in total) and all students undertake a full-time 20-week industrial placement during their 5th or 6th semester. In their final semester, the students complete a 20 ECTS point B.Eng. project in industry. The primary learning outcome of the B.Eng. final project is defined as the practical application of technical knowledge concerning innovation, development and solution of technical problems including all the CDIO phases.

The benefits of close collaboration between academia and industry are well described and documented in the literature. These include enhancing the employability of graduates and faculty development (Tiewtoy, Krusong & Kuptasthien, 2019) and developing interpersonal skills (Säisä, Määttä, Roslöf, 2019). Establishing and maintaining close cooperation with companies is not without challenges as Male et al. (Male, King, Hargreaves 2016) describe. Companies can experience a lack of a clear, convenient and coordinated system of contact in universities. Time and other resources required for student supervision can also provide a barrier to collaboration. Having been the academic supervisor for many student final projects over many years, the authors have also observed other additional factors which also act as barriers and limit the desired outcomes of the industrial collaboration when considering industrial placement and final projects. These problems are described below and an industry roadmap is presented which has been demonstrated to be effective in addressing these problems as well as those as described by Male et al. (Male, King, Hargreaves 2016).

Challenges within Small or Medium-Sized Enterprises

In Denmark, 99.7% of public and private companies are classified as being small or medium-sized enterprises (SME) since they have fewer than 250 employees (European Commission, 2019). Danish companies' expenditure on research and development is 2.0% of the Gross Domestic Product (GDP) which is significantly higher than the European average of 1.4% (Statistics Denmark, 2020). This means that the B.Eng. students at the Technical University of Denmark typically undertake their industrial placement and B.Eng. final project in highly specialized small or medium-sized companies and work on highly specialized projects.

The specialized nature of companies and projects presents several challenges relating to the individual student and also any subsequent students who may follow and undertake their final project within the same company. The timescale for the project is 12 weeks. Therefore, when the student initially starts working on their final project within the company, they are faced with a very steep learning curve in terms of acquiring specialized knowledge of e.g. the technical domain, technology, equipment, standards and company procedures etc. This also requires a high initial investment of time and resources from the technical supervisor within the company. This investment by the company supervisor must be repeated for each subsequent student starting their final project within the company. This is both inefficient and expensive and may prevent companies from offering projects.

Upon completion of the final project at the end of the 12 weeks, it is not uncommon for the student to be offered employment within the company. This is a desirable outcome and proves the benefits of integrated learning experiences (Standard 7). What can also happen though, is that the student after handing in their final project report and attending their final examination, finds employment elsewhere. This can have several negative outcomes. Due to time and resource limitations, the company supervisor may not be fully briefed about all aspects of the project before the student leaves the company. This means that the company does not obtain the full potential value of the project and may need to use unnecessary resources to continue developing the project. If for some reason there are no students following immediately within

the company, the continuation of certain research and development activities within the company may not be continued due to lack of resources. The lack of final project students within the company may also potentially result in a decrease in communication and collaboration between the company and academic supervisors.

The industry roadmap described below for strengthening CDIO in B.Eng. final projects has shown to solve these problems and enhance university-industry cooperation.

INDUSTRY ROADMAP FOR STRENGTHENING CDIO

The objective of the roadmap is to strengthen the implementation of the relevant CDIO standards concerning industrial placement and the final project in B.Eng. programs at the Centre for Bachelor of Engineering Studies at the Technical University of Denmark (DTU Diplom), in particular concerning validating learning outcomes (Standard 2), evaluating the design implement experiences (Standard 5) and the integration of learning experiences (Standard 7) with SMEs as stakeholders. The involvement and benefits of SMEs as stakeholders in CDIO projects has been described by Nordfalk et al. (Nordfalk, Bridgwood, Nyborg, 2018). A process for the longer-term involvement of SMEs in taught courses has also been described by Bridgwood et al. (Bridgwood, 2017).

The objective is achieved by establishing strategic collaboration with companies and defining research and development projects which require more resources than an individual final project or industrial placement. A flow of students undertaking industrial placement and subsequent final project is achieved and most critically, the exchange of knowledge acquired is ensured. The roadmap steps involved in the process are described below:

1. An initial discussion is undertaken between DTU Diplom and the relevant company where the company's requirements and areas of interest for research and development are identified and documented. This is done for both short- and long-term timeframes.
2. DTU Diplom publishes the available position(s) for industrial placement after an agreement with the company.
3. The company selects the appropriate candidate(s) who then undertakes and completes their industrial placement which is subsequently documented by a report.
4. Having completed their internship, the student then commences their B.Eng. final project within the company. The topic for the final project is established and agreed upon towards the end of the internship.
5. At the same time as the student commences their final project, another student commences their internship within the company.
6. When the student completes their final project, they are required to submit a technical profile status document along with the compulsory final project report. The technical profile status document is described below.
7. The above steps are repeated such that at any one point in time, a student is undertaking an internship along with a student undertaking their final project. This overlap is one of the essential elements in ensuring that the transfer of knowledge is maximized. This is illustrated in Figure 1.

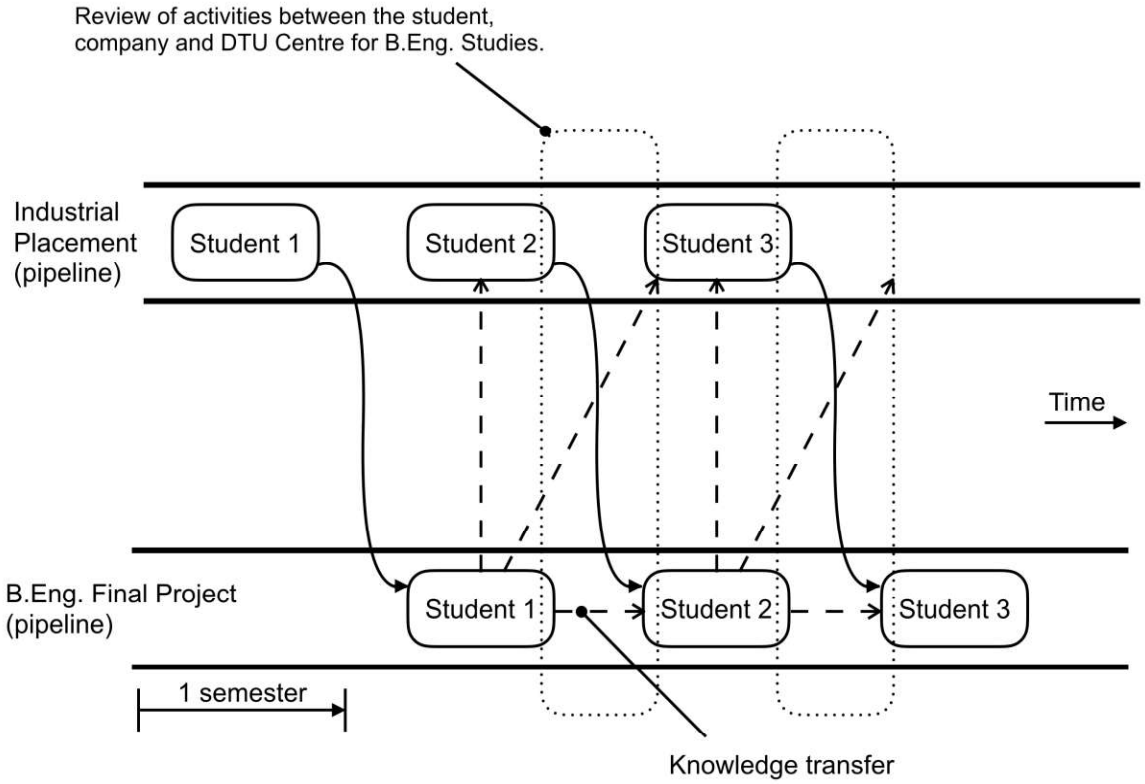

Figure 1. Flow and interaction of students within a company

Figure 1. illustrates the continuous flow and interaction of students within a company, represented by two pipelines. The industrial placement pipeline shows how a student e.g. Student 1, at the end of their 20-week internship, is followed by another student e.g. Student 2 who will eventually be followed by another student e.g. Student 3 and so on. At the end of their internship, the student will then progress to the B.Eng. final project pipeline and be part of the continuous flow of students subsequently undertaking their final project. In Figure 1, the dashed lines emanating from each student in the final project pipeline represent communication and knowledge transfer between students at various levels and stages. In Figure 1 above, consider e.g. Student 1 in the B.Eng. final project pipeline:

- Having completed their internship and now undertaking their final project, Student 1 can provide valuable knowledge and advice for Student 2 who is undertaking their internship.
- Upon completion of their final project, Student 1 can provide valuable knowledge and advice for Student 2 who is about to commence their final project and also to Student 3 who is about to commence their internship.

At the end of a B.Eng. final project period, a status review meeting is held between the company, DTU Diplom and the current and prospective students in the industrial placement and B.Eng. final project pipelines. The purpose of the meeting is to undertake a retrospective review of the research and development activities completed and to plan future short- and long-term activities. An input to the review is the technical profile status (TPS) document which the student generates in cooperation with the company and DTU Diplom, in addition to the student writing their final project report. The TPS document includes short- and medium-term recommendations for the following B.Eng. final project period along with literature, software

and equipment references. Furthermore, the TPS also contains checkpoints for ensuring that the DTU Diplom information channels to the students, announcing the internships together with the technical contents of these are updated in agreement with the decisions made between the student, the company and DTU Diplom at the review meeting. In Figure 1 above, the status review is illustrated by the dotted rectangle bridging the two pipelines. This communication ensures that the knowledge sharing between the company, DTU Diplom and the students is maximized whilst also strengthening the students' interpersonal and operational skills. Furthermore, it is recommended to carry out the TPS review at the same meeting between the student, the company and DTU Diplom, where the assessment of the B.Eng. final project is carried out, thus avoiding spending additional overhead time in the final project supervision process.

RESULTS

The industry roadmap described has been successfully implemented since 2018 in a continuing cooperation with Dansac A/S (Dansac 2020), a leading manufacturer of stoma products. A series of industrial placements and B.Eng. final products have been undertaken and completed in collaboration with Dansac's Business Improvement Division. The students' research and development activities have primarily been focused on manufacturing process characterization and quality control and have been very varied. Projects have included, for example, measuring and analysing the cooling profiles of polymer products in a manufacturing line and utilizing a 3D scanner to access the criticality of component dimensions in composite structures. The varying short- and long-term areas of interest for investigation have had the added benefit that the students are working on multidisciplinary projects with the students themselves coming from a variety of B.Eng. degree programs. The programs have included B.Eng. Healthcare Technology, B.Eng. IT Electronics, B. Eng. Electronics and B.Eng. Mechanical Engineering.

Continuity is a fundamental aspect of the industry roadmap and this continuity between the company and the same university faculty members acting as the academic point of contact and supervisor has also contributed to the enhancement of faculty competence (Standard 9) in the setting of Dansac A/S.

CONCLUSIONS AND FINAL REMARKS

An industry roadmap for strengthening CDIO in B.Eng. final projects has been presented. The results of having implemented the roadmap since 2018 have demonstrated an increased level of collaboration and communication between the university and industry. As part of the roadmap, regular biannual reviews held between the university, company and students enable the program learning outcomes to be revised based on changes in the stakeholder's, i.e. the company's needs (Standard 2). Similarly, the meetings also provide a forum for the evaluation of the design-implement experiences of the B.Eng. final projects
based on feedback from the students, academic supervisor and company supervisor (Standard 5). The students undertaking their industrial placement and B.Eng. final project are required to convey their findings and conclusions to their peers and supervisors to a greater extent than previously which strengthens the inherently integrated learning experience (Standard 7).

Adoption of the roadmap does not involve any contractually binding obligations for the company involved, the agreements are based upon informal declarations. The long-term cooperation is often driven by enthusiastic individuals within the company and is therefore potentially vulnerable to staff turnover. Similarly, undertaking an industrial placement and B.Eng. final project in the same company is not required by the academic regulations and a student may choose to undertake their B.Eng. final project in a different company.

The longer-term collaboration concerning industrial placement and B.Eng. final projects has reinforced the implementation of CDIO standards and provided additional benefits for the companies involved. DTU Diplom is currently actively engaged in establishing cooperation with additional companies for them to adopt the roadmap.

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