UNIVERSITY AND CONTINOUS ENGINEERING EDUCATION – PERSPECTIVES ON INTEGRATING STUDENTS

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ABSTRACT

Practical and relevant competence ready to apply in an industrial setting is of crucial importance for University Engineering Education (UEE). However, what is considered as industrial relevant knowledge and skills are changing in an increasing pace and the gap between the research front and application in industry is decreasing. Within manufacturing industry, engineers must be able to jointly optimize the design and operation of manufacturing systems and products, transferring newest research, knowledge, and technology into the business at fast pace. Continuous Engineering Education (CEE) commonly involves development of theoretical skills together with the practical work in a company setting. In this paper, learning activities comprising both CEE and UEE students are studied. By mixing students from the two groups potential benefits could be achieved within each group. The purpose with the paper is to describe how learning activities integrating CEE and UEE can be achieved to strengthen the CDIO goals as well as exploring the benefits and challenges related to the mixed student group. Learning activities combining the student groups were studied in 4 CEE courses. Several types of learning activities gathering the student groups were identified including project work in industrial settings, lecture discussions, and project presentation seminars. Challenges identified related to e.g., the differences in background knowledge and skills in the areas affecting the design of project works as well as practical factors such as scheduling.

KEYWORDS

Continuous engineering education, Lifelong learning, Mixed student groups, Standards: 7 (Integrated Learning Experiences), 8 (Active learning), 9 (Enhancement of Faculty Competence)

INTRODUCTION

To prepare engineering students for future working life through hands-on learning characterized by active learning methods encouraging problem solving and practical engagement is a corner stone in CDIO-based education. The importance of practical and relevant competence ready to apply in an industrial setting is crucial for University Engineering Education (UEE). However, what is considered as industrial relevant knowledge and skills are changing in an increasing pace and the gap between the research front and application in industry is decreasing in many areas such as in production development and Industry 4.0. (Medini, 2018). The latest theory and research must faster be transferred into industrial applications in order to secure industrial competitiveness (Fink, 2002). The UEE students play a crucial role in this transformation as carrier of knowledge and skills based on recent research and theory. However, it is a challenge to keep the industrial relevance of UEE up to date due to the rapid industrial development.

Employment of UEE students in industry is one mean to disseminate knowledge and skills to industry. However, due to the fast industry development there is also an increasing need for continuous lifelong education for industrial professionals to constantly update the knowledge and skills. Within the field of industry 4.0, engineers in manufacturing industry must be able to jointly optimize the design and operation of manufacturing systems and products, transferring newest research, knowledge, and technology into the business at fast pace. The pressure to constantly increase and develop knowledge and skills is increasing in an accelerating pace. Life-long-learning, also labeled as Continuous Engineering Education (CEE) within the engineering field, usually involves development of theoretical skills together with the practical work in a company setting (Fink, 2001). Compared to UEE, the need for work-setting relevancy and application of learning to companies and daily work is strong and must characterize the CEE education.

Both student groups are crucially important for the manufacturing industry. However, the student groups normally differ in terms of e.g., theoretical, and industrial knowledge and skills, working experience, and age. Due to this difference, combined with the mutual goal to achieve industry relevant knowledge and skills, there is a potential future avenue to mix the student groups in learning activities. Therefore, in this paper, learning activities comprising both CEE and UEE students are studied. By mixing students from the two groups potential benefits could be achieved within each group. The purpose with the paper is to describe how learning activities integrating CEE and UEE can be achieved to strengthen the CDIO goals as well as exploring the benefits and challenges related to the mixed student group.

THEORETICAL BACKGROUND

Industry relevant university engineering education

The CDIO initiative aims to develop engineering education that prepare students with knowledge and skills for their future working life as engineers. Engineering graduates from a CDIO based education should be able to conceive, design, implement, and operate complex value-added engineering systems in a modern team-based engineering environment (Brodeur & Crawley, 2005). Courses should, thus, both be of relevance for manufacturing industry and be structured in a way that the students get prepared for the way of working as engineers. The CDIO standards (Crawley et.al., 2014; Bennedsen et.al., 2016) is a guidance for course developers in this task where several standards are explicitly referring to the industrial relevance, such as:

- Introducing students in tasks and responsibilities of an engineer, and the use of disciplinary knowledge in executing those tasks (Standard 4)
- To create design and implement experiences by letting the students develop product, process, and system building skills. Also, to develop the ability to apply engineering science, in design-implement experiences (Standard 5).

- To get used and learn in engineering workspaces that support and encourage hands-on learning of product, process, and system building, disciplinary knowledge, and social learning (Standard 6)
- To incorporate professional engineering issues in contexts where they coexist with disciplinary issues (Standard 7)
- To arrange for learning based on active experiential learning methods (standard 8)
- Enhance the faculty competence including for example professional leave to work in industry, partnerships with industry colleagues in research and education projects, inclusion of engineering practice as a criterion for hiring and promotion, and appropriate professional development experiences at the university (Standard 9).

All these aspects call for courses with high industry relevance and to prepare students for the current engineering tasks directly after graduation. The benefits of decreasing the gap between industry and UEE have often been researched and discussed in the CDIO community. To use project work and internship as central learning activities increases the industry relevance of UEE. In a survey Munoz et.al (2019) show that internships for engineering students strengthen their technical knowledge as well as interpersonal skills. They stress that the courses need to be adapted for industry collaboration and the value for both industry and academia need to be secured. Moreover, the positive effects to include project work together with industrial companies to solve actual problems through problem-based learning is described by e.g. Martins et al. (2019) and Grishmanovskiy et.al. (2020). A roadmap for improving knowledge dissemination and value creation for both university and industry and the students was proposed by Bridgwood & Sørensen (2020). The value of bridging the gap between academia and industry in different learning activities has got large attention. Still, there is limited research related to CEE and bridging the gap related to this type of education.

Continuous Engineering Education

Lifelong learning education including professional development and continuing education has traditionally been an activity run by private providers of courses and not by universities. CEE or continuing professional development (CPD) commonly includes the development of theoretical skills alongside the practical work in a company setting. The need for work-setting relevancy and application of learning to companies and daily work is stronger compared to UEE (Fink, 2001; Fink, 2002). Due to the increasing need for CEE and the need to fast reach out with the latest knowledge based on research, universities have become an important provider in this field (Fink, 2002). In Swedish universities a large number of courses for professionals on advanced level, i.e., on master level, has been developed closely related to the developed research. Both advantages and challenges have been identified related to CEE courses on advanced level. There are large differences between CEE education and UEE both in terms of the students' previous skills and concerning requirement of the content of the course. The CEE student normally requires immediate application of the theories into their daily practice (Fink, 2002). In a study by Andersen and Rösiö (2021) the challenge to translate novel research results to knowledge ready to apply in industry was highlighted. Often, the course literature is a challenge and the literature available are journal articles, not easy to comprehend for the CEE student.

In a five-stage framework for lifelong learning in engineering education and practice Uhomoiibhi and Ross (2019) describe the phases of Pre-employment, Early Employment, Mid-Career Employment, Later Employment, and Post Employment. This framework intends to show the large spectra of potential students where only the first phase would represent UEE while all the other represents CEE. It is crucial to establish a link between education, lifelong learning and employment and the framework show the complexity in the variance of students (Uhomoibhil & Ross, 2019).

METHODOLOGY

In this paper, courses developed within a project called PREMIUM were studied. In the project 9 CEE courses within the field of knowledge intensive production development were developed for professionals by School of Engineering, Jönköping University. The courses were advanced level courses of 5 ECTS credits, running on 25% pace. The courses were designed to enable combining studies with a full working position. The courses were initially planned to include a mix of online events and face-to-face meetings. Due to the Covid 19 pandemic the main part of the course occasions were accomplished online. The courses were supposed to follow a pedagogical model including co-reading with UEE courses within the master programs, figure 1.

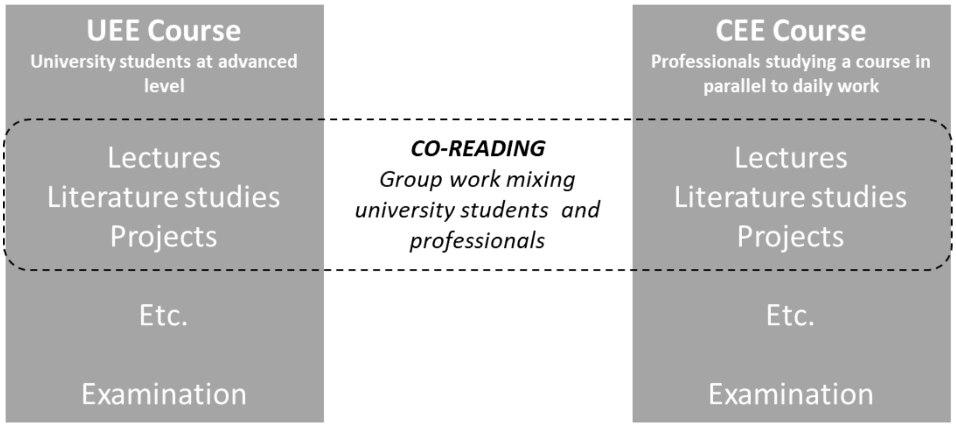

Figure 1. The principle of co-reading in certain activities in UEE and CEE courses

Relations and synergies towards similar courses within 4 CDIO based UEE programs at master level were considered during the development. The 9 CEE course syllabuses were compared with the course syllabuses of the master programs to identify similarities. Based on this, a matrix was established matching CEE courses to UEE courses, figure 2. Thereafter, the matrix was followed up with the program manager, main responsible for the different master programs. Finally, the matrix was presented for the CEE and UEE course responsible. Consequently, all CEE courses in the PREMIUM program were connected to at least one master program course to give prerequisites for all CEE courses to apply the principle of co-reading. Thereafter, it was the responsibility of the course leaders to decide if and how joint reading would be implemented in the CEE course. In this study both CEE courses and the master programs were under development. Thus, in some cases the co-reading was not yet possible due to that the courses had not been conducted when this study was made.

	CEE Course 1	CEE Course 2	CEE Course 3	CEE Course n
UEE Course 1				
UEE Course 2		*Description of content to be shared in the courses*		
UEE Course 3				
UEE Course n				

Figure *2*. Principle of matching content between UEE and CEE courses

In this paper, learning activities combining the student groups were studied in the CEE courses within the PREMIUM project. Data collection was initially done through interviews with course responsible. 9 course responsible persons where interviewed. 4 of the courses had applied co-reading, therefore, these courses were focused in the study. The interview questions included 11 questions:

1. What is the name of your Premium course?
2. Have you gathered program students and master's students in the course on any occasion?
3. On how many occasions in the course did you gather program students and master's students?
4. What master program did the students study?
5. What was the name of the course the master students were studying?
6. In what type of activity did you gather the student groups?
7. Describe with a few sentences the activity/activities.
8. What was the main purpose with gathering the students?
9. Describe the main values of mixing the student groups.
10. Describe the main challenges of mixing the student groups.
11. Do you want to share some other reflections related to the topic?

The interviews were followed up with document study including course information documents and course syllabus.

RESULTS

Four courses had applied co-reading between CEE and UEE students. Among the ones that had not applied the principles of co-reading the reasons were, among others, that the CEE course or the UEE course was given for the first time, and it was a too complex task to involve two target groups at this initial stage. In some cases, they could not establish co-reading due to practical reasons such as scheduling or different course pace.

All courses involved design and development of new production systems or work procedures but related to different areas. In all courses a CDIO approach was applied since problems were investigated in relation to the CEE students own practice covering the stages of conceive design, implement, and operate. The operate phase, however, consisted of discussions and analysis of developed solutions related to the use of the implemented production system or work procedure to reach the intended value.

The four courses that applied the principles of co-reading and, thus, were studied in this paper had the titles: (1) Agile production development, (2) Changeable and reconfigurable manufacturing, and (3) Human Factors Engineering, and (4) Maintenance for production performance.

In the course Agile production development, the student learned about agile principles for effective implementation of projects in production development. The course was alternating theory and practice, adapted to the needs of the participants daily work or industrial experience. The course covered all phases of a project, from initiation and planning to implementation and project completion. Co-reading was applied with master students from a course covering similar topics. The co-reading included participation in the same lectures. The main values for co-reading were, according to the course responsible, for CEE students to get recent knowledge in the field and for the UEE students to build a network of contacts for future employment. The course did not apply co-reading related to the project work since it required practical experience and a work position to which the projects where connected. The UEE did not have enough practical experience neither a working position.

The course Changeable and reconfigurable manufacturing intended to build competence in design and development about changeable production systems to provide efficient production to better deal with variations in e.g., product types and volumes. The course was centered around a project work where the CEE participants continuously applied theories to practice in order to develop a conceptual reconfigurable production system. In this course UEE students were invited to attend lectures and project presentations in the CEE course. The UEE students were master students from the final course of their program, Final project work in production systems. The students invited to the CEE course were, thus, students doing master thesis projects within the topic. The reason to involve these UEE students were to broaden the student knowledge in the field and to get the opportunity to learn from other companies, except the ones that they collaborated with in their thesis project. The CEE students were invited to participate in thesis project presentations by the UEE students. Also, this was an opportunity to discuss and learn from each other on the topic.

The course Human factors engineering provided knowledge and insights on how products and industrial systems could be designed considering people's natural strengths and limitations and result in usability, efficiency, sustainability, and well-being. In this course the industrial problems by the CEE students were investigated by the UEE students. The CEE students formulated a problem from their organization that was interesting to get investigated related to the topic of the course. Project works for the UEE students were defined based on the problems. The CEE students had the roles of supervisors related to their own problems. This approach of co-reading aimed to support the CEE students in their learning related to their own industrial problem. By acting as supervisor, they had to explain and discuss the problems related to new theories with UEE students. The UEE students got the chance to investigate a real industrial problem with supervision from a professional. This concept involved several challenges. It required a lot of time from the course responsible since he had to guide the CEE students in supervision as well as guide the UEE students related to the theoretical field. Another challenge was to be one step ahead and creating the vision for the benefits from the next step, without constraining too much the relationship between the CEE and UEE students. It was important to allow them freedom to create their own bonds and positive mutual enhancements but pointing a path at the same time for collaboration. This type of co-reading was seen as a win-win way of working, for all the parties involved. The UEE students appreciated to be in contact directly with company employees sharing the same interests and learn from them. From a teacher perspective, besides an increased learning, the teacher was strengthening his leadership skills managing the interaction between the two groups in a growth approach for everyone. The CEE student got their problem investigated by students.

In the course Maintenance for production performance the CEE student gets knowledge and skills to motivate a maintenance strategy to develop the company's production performance. In this course, the participants were invited to participate in two guest lectures about how production flow simulation was applied and used in practice. The guest lectures were given together with students in a third cycle course (PhD level). The reason for this co-reading was to get maximal advantage of the opportunity to learn from this experienced guest lecturer since it was a relevant topic for both student groups.

In each of the courses co-reading had taken place between 2 and 5 times. The courses were on advanced level and the UEE students were master students, and in one case PhD students. In none of the co-reading activities mutual examination were conducted. Only in the course in Human factors engineering the co-reading activity was a compulsory activity in the course.

DISCUSSION

In order to strengthening the competence within manufacturing industry education for professionals (CEE) and traditional education (UEE) play an important role. The types of co-reading activities identified in the courses in this study were:

- participation in the invited guest lectures – UEE and CEE students were gathered in the same classroom (virtual or face-to-face) to listening to the invited guest lecturer and get the possibility to discuss the topic of the lecture
- participation in lectures by university teaching staff – same as above, but the teacher was the regular teacher of the UEE and/or the CEE course
- seminars and project presentations – UEE and CEE students met to discuss e.g., project results or course literature
- project work –UEE students worked with problems identified by the CEE students supervised by the CEE student and the teacher of the course

The activities differed in terms of character, extension, and purpose. By combining the student groups in different types of activities benefits for both UEE and CEE student as well as the teacher/course responsible could be identified. In the same way challenges could be identified related to the three roles. In table 1, the benefits and challenges with the co-reading activities are summarized related to the three different roles.

Co-reading activities should ideally lead to a win-win situation between the two student groups. If it only benefits one of the groups or the challenges are large in relation to the benefits the value of the co-reading activity might be pointless. The value for the teacher is also a perspective to highlight. This type of activities was in the courses contributing to enhancing the faculty professional competence (Standard 9), according to the course responsible teachers. The project has strengthened the ability to support students to achieve a deeper working understanding of the relevant disciplinary fundamentals, which is something that is addressed in this standard.

Many different aspects might affect the extent of the benefits in the co-reading activities. The professional experience can highly differ between CEE students, according to the framework by Uhomoibhil & Ross (2019). In the CEE courses participants with a large variety in competence and working experience were included, from persons that were recently graduated and newly employed to students with a very long and qualified working experience. Also, the size of the student groups affected the benefits of the co-reading. The size of the student groups differed between approximately 5-20 students. In small student groups the co-reading was more motivated than in larger groups in order to increase the number of perspectives by the students.

Table 1. Overview of co-reading activities and related challenges and benefits

	UEE student	**CEE student**	**Teacher/ Course responsible**
Participation in the invited guest lectures	+Industry perspective in any discussions/ questions		+Increased possibility to invite guest lecture due to a larger student group
Participation in lectures by university teaching staff	+Industry perspective in any discussions/ questions -Less focus on the UEE students' needs	-Less focus on the CEE students' needs	+ Save time
Seminars and project presentations	+Get the industry perspective into the discussion	+Get the perspective from UEE students with "fresh eyes"	+ Increased learning through the two perspectives
Project work	+Possibility to work with industry relevant problem and be supervised by a professional	+Get "fresh eyes" on their industrial problem as well as support in solving the problem -Spend time on supervising the UEE students	+ Support in identifying relevant industrial problems +Support in supervising the UEE students -Spend time on training the CEE students in supervision -Spend time in supervising the UEE students on the theoretical part of the problem -Require more planning/organizing

In this study both the CEE (the PREMIUM courses) and the UEE (the master programs) were recently developed and only held one or a few times. Some of the master courses that were matched to the CEE courses in accordance with the matrix (described in figure 2) were under development and still not carried out. Consequently, the concept of co-reading was still not fully established. To fully develop and draw advantage of the concept a higher level of maturity is required in both the UEE and the CEE courses.

This study perhaps most clearly contributes to strengthening standard 7, Integrated Learning Experiences, where it is pointed out that incorporating professional engineering issues in contexts where they coexist with disciplinary issues is important. UEE students have gained an industry perspective on their issues and problems. They have also been given the opportunity to work with industry-related tasks and have been supervised by professional CEE students.

Standard 8, Active Learning, has also been strengthened through the PREMIUM project. The project has given UEE students the opportunity to get involved in and to solve real industrial problems. They have discussed in small groups together with professional CEE students and had the possibility to debate various concepts and solutions.

CONCLUSION

The purpose with the paper was to describe how learning activities integrating CEE and UEE can be achieved to strengthen the CDIO goals as well as exploring the benefits and challenges related to the mixed student group. Several types of learning activities gathering the student groups were identified in this study including project work related to problems formulated by CEE students, lecture participations and discussions, and seminars. Benefits and challenges related to the UEE student, CEE student, and teacher were identified. In the study the co-reading benefited the three roles in different ways. The UEE student got increased insights in the industry perspective while the CEE student widened their perspective through the co-reading with UEE students. The co-reading activities also contributed to enhancing the faculty professional competence. Challenges identified related to e.g., the differences in background knowledge and skills in the areas affecting the co-reading activities in lectures and in project work as well as practical factors such as planning and scheduling. The results indicated clear relations to CDIO standards related to (7) Integrated Learning Experiences, (8) Active learning, and (9) Enhancement of Faculty Competence.

FINANCIAL SUPPORT ACKNOWLEDGEMENTS

The Swedish Knowledge Foundation is greatly acknowledged for financing and contributing to the PREMIUM project.

REFERENCES

Andersen, A.-L., & Rösiö, C. (2021). Continuing Engineering Education (CEE) in Changeable and Reconfigurable Manufacturing using Problem-Based Learning (PBL). *Procedia CIRP*, *104*, 1035–1040.

Bennedsen, J., Georgsson, F., & Kontio, J. (2016). Updated Rubric for Self-Evaluation. *Proceedings of the 12th International CDIO Conference*. Turku, Finland: Turku University of Applied Sciences.

Bridgwood, I., & Sørensen, J. A. (2020). Strengthening CDIO in B.Eng. final projects with an industry roadmap. *Proceedings of the 16th International CDIO Conference*. Gothenburg, Sweden: Chalmers University of Technology..

Brodeur, B., & Crawley, E. F. (2005). Program Evaluation Aligned with the CDIO Standards. *Proceedings of the 2005 ASEE Conference*.

Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D., & Edström, K. (2014). *Rethinking Engineering Education – The CDIO Approach* (2nd ed). Springer-Verlag.

Fink, F. K. (2001). Modelling the context of continuing professional development. *Proceedings - Frontiers in Education Conference*, *1*, 19–24.

Fink, Flemming K. (2002). Continuing Engineering Education: a New Task for Universities in Denmark. *Global Journal of Engineering Eductaion*, *6*(2).

Grishmanovskiy, P., Grishmanovskaya, O., & Zapevalov, A. (2020). Project training in the implementation of practice-priented disciplines. *Proceedings of the 16th International CDIO Conference*, *June*, 8–10. Gothenburg, Sweden: Chalmers University of Technology.

Martins, Â., Bragança, A., Bettencourt, N., & Maio, P. (2019). Project-based learning approach in a collaboration between Academia and Industry. *Poster Presentation at the 15th International CDIO*

Conference. Aarhus, Denmark: Aarhus University.

Medini, K. (2018). Teaching customer-centric operations management–evidence from an experiential learning-oriented mass customisation class. *European Journal of Engineering Education*, *43*(1), 65–78.

Muñoz, M., Martínez-araneda, C., Basso, M., Oyarzo, C., Cea, P., Bizama, M., & González, H. (2019). Senior-year internships impact assessment in engineering programs at UCSC. *Proceedings of the 15th International CDIO Conference*. Aarhus, Denmark: Aarhus University.

Uhomoibhil, J., & Ross, M. (2019). The Five Stage Framework for Life Long Learning in Engineering Education and Practice. *INSPIRE XXIV, Twenty-Fourth International Conference on Software Process Improvement Research, Education and Training: Global Connectivity and Learning Across the Nations.*, 11.

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