ENGINEERING STUDENTS' INTERACTION WITH INDUSTRY REPRESENTATIVES

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ABSTRACT

The aim of this paper is to share and reflect on experiences of learning activities, in which engineering students meet with representatives from industry and public organisations to get acquainted with realistic engineering issues. The paper is based on experiences from two learning activities at Linköping University, which aim at making the engineering students familiar with realistic industrial issues. The first activity is a course in Lean production, in which a half-day conference is organised where representatives from industry and public organisations describe how they work with Lean in practice. The second consists of courses in Six Sigma, in which the students carry out Six Sigma and Quality Management projects in different companies. Data regarding the students' experiences, learning and opinion about interaction with industrial and public sector representatives during their education were collected through questionnaires and interviews. The industrial representatives' views were similarly collected through interviews and written evaluations. The findings are that the learning activities were highly appreciated. They gave a good picture of real working-life issues and were relevant to the students. In the Six Sigma projects, the students specifically described that they learnt a great deal, both about Six Sigma and about project management, how to describe their work in new ways, and how to solve practical issues. The industrial representatives expressed that they were satisfied with the students' work, their competence, and the final result. It was beneficial that the students looked at the company problems from an outside perspective and that they contributed to knowledge sharing within the company. Experiences of organising these learning activities include highly positive feedbacks from students and participating organisations. For the teachers, even though it implies a lot of work, it is also a very positive experience contributing individual insights and life-long learning.

KEYWORDS

Active learning, Real-world engineering issues, Quality Management, CDIO Standards: 5, 7, 8

INTRODUCTION

Earlier studies highlight the importance of developing higher education in engineering to support the students' understanding, problem-solving skills and ability to apply knowledge in real-world situations (Bishop & Verleger, 2013; Mason et al, 2013; Arrambide-Leal et al, 2019). By carrying out the engineering studies in realistic contexts the students learn about current

issues in industry and public organisations and that engineering consists of solving complex, open-ended problems. They also learn how their own knowledge fits with reality, and they get some insight into possible future work directions. This can be achieved through different approaches that enhance the students' deep learning in which the students reflect on the meaning of ideas and theories and how these can be applied in real-world situations (Marton & Säljö, 1976). A deep approach may be encouraged through four principal factors (Biggs, 1989):

- An appropriate motivational context
- A high degree of learner activity
- Interaction with others, both peers and teachers
- A well-structured knowledge base

The high degree of learner activity is also referred to as Active learning. The students then generally receive instructions in the classroom for forthcoming learning activities that encourage student activity and require the students to be more engaged in their learning process and reflect on what they do (Prince, 2004). Active learning is also one of the CDIO standards (Standard 8), advocating that the students should be directly engaged in problem-solving activities. This can include small-group discussions, demonstrations, etc. and even be experiential when the students simulate professional engineering practice (CDIO, 2021). One type of active learning is problem-based or project-based learning, which has been adopted within engineering education to improve the students' skills in problem-solving and collaboration (Zhu et al, 2019).

The importance of supporting the students' ability to understand and apply knowledge in real-world situations is also highlighted in other CDIO standards, such as Design-Implement Experiences (Standard 5) and Integrated Learning Experiences (Standard 7). The idea of Design-implement experiences is to aid the students to integrate knowledge and skills to promote early success in engineering practice. This can evolve throughout the students' educational programme and in later courses be included in learning activities involving real-world issues, for example in different types of projects with external stakeholders. It is here important to regularly evaluate the design-implement experiences from students, teachers, and external stakeholders (CDIO, 2021). The CDIO standard Integrated Learning Experiences similarly highlights pedagogical approaches that combine professional engineering issues in contexts with other disciplines and issues. This can be done by elaborating on real-world cases, which help the students to be better prepared for the future demands of the engineering role (CDIO, 2021).

There are different ways to achieve realistic contexts for the students' learning activities. Keeping this in mind when designing courses, brings different opportunities depending on the students' prior knowledge and skills, course resources, etc. Within the courses in Quality Management at Linköping University, different means are used to support learning activities in which the students meet with representatives for industry and public organisations. In this paper, experiences from a course in Lean Production and project courses in Six Sigma and Quality Management are described. In particular, the aim of this paper is to share and reflect on experiences of learning activities, in which engineering students meet with industry representatives and get acquainted with realistic engineering issues.

METHOD

The paper is based on experiences from two learning activities at Linköping University that aimed at making the engineering students familiar with realistic industrial issues. The first activity was within a course in Lean production, in which a half-day conference was organised where representatives from industry and public organisations described how they worked with Lean in practice. The second activity was within Six Sigma courses, in which the students carried out Six Sigma and Quality Management projects in different companies. As the two learning activities were independent from each other and given by different teacher groups, the evaluation data were developed to fit each teaching activity.

Data regarding the first activity, the Lean conference, were collected through 17 student questionnaires, individual and group interviews with in total 12 students (8 students after a course with the Lean conference at the university and four students after a course with a digital Lean conference). Furthermore, reflection documents submitted by the students after the conference were also examined. The reflection document was a course assignment where the students reflected on what they had learnt from the Lean conference. The questionnaire was an evaluation of the Lean conference and how the content contributed to the students' understanding of real-world issues, how Lean is applied in practice, and the usefulness for the students' future professional role. Data from the questionnaire were quantitatively analysed using the statistics analysis software MiniTab. These findings were presented in a boxplot (see Figure 1) due to its usefulness in visualising data such as mean and median values as well as spread in a clear way. The group interviews focused on experiences, learning and the students' opinions about collaboration with working life during their education. The students participating in the group interviews included those who had performed their undergraduate studies in Sweden, southern Europe and Asia. Qualitative analysis of the data from the questionnaire, interviews and reflection document was conducted using thematic categorisation. Some of the themes from the questionnaire was adopted such as positive and negative learning outcomes and knowledge gained during the conference.

Data for the second activity, the Six Sigma and project courses, were collected through semi-structured group interviews with six students and three individual interviews with industrial representatives that had participated in Six Sigma projects. The students evaluated their project work, while the interviews with the industrial representatives focused on their experiences, prerequisites for, and requests regarding collaboration with the university. Feedback from 100 organisations participating in the Six Sigma project course during the period of 2013 to 2021 were also examined.

LEARNING ACTIVITIES

The course in Lean Production

The course in Lean production is given in English and has a case-based design. Many of the students taking the course study one of the Swedish engineering programmes or international master's programmes. Most years, more than 100 students attend the course. Due to travel restrictions during the corona pandemic, a lowered number of students applied to the university and thus the number of students in the course dropped to approximately 70 students in 2021. Lean production is a management philosophy that has its roots in the car industry in Japan. The philosophy thus has a strong industrial connection and tradition, which the course is designed to emphasise. The course is examined through four assignments - three mandatory

group assignments and one optional individual assignment, that are connected to specific theoretical themes such as Lean principles and tools, Lean implementation, leadership and change management. Although the most prominent application of Lean is in the industry setting, the course also addresses how the philosophy has been introduced and translated into other settings, for example in public organisations. Each assignment is based on a fictious case organisation to provide the students with opportunity to relate the course content to different contexts. To further strengthen the connection to the industry and give students real-life examples of how Lean has been implemented in different organisation, a Lean conference is held at the end of the course.

The Lean conference is a seminar where representatives from industry and public organisations present how they work with Lean in their organisations and participate in a panel discussion. Based on the submitted questions, the conference moderator, usually the course director, sorts and selects relevant and interesting questions to be discussed by the panel. During the years, the format of the conference has varied in regard to location, time and presentations. It has been a physical on campus seminar as well as a digital seminar, lasting for 2,5 to 4 hours and containing 1-4 presentations and a panel discussion. After the Lean conference, each student individually submits a short reflection document about what they learned during the conference.

Courses in Six Sigma and Quality Management

The teaching of Six Sigma within the quality management (QM) department is organised as a two-stage rocket. First, after taking the basic QM courses, the students interested in Six Sigma must take the theoretical Six Sigma Quality course, and then, if they want to, they may take the Six Sigma project course, both being advanced courses. The number of students vary but around 60 students in the Six Sigma Quality course with four students per group and around 30 students in the Six Sigma project course, with two students per group. Half of the students are from Sweden and half from abroad. All teaching is conducted in English.

The reason for the two-stage rocket is that previous experiences have showed that students may have problems learning the Six Sigma project phases DMAIC (*Define-Measure-Analyze-Improve-Control*), including all the statistical and qualitative tools, and at the same time solve a real problem at a real organisation. The 'basic' Six Sigma Quality course is designed as a Six Sigma project with the five phases DMAIC, with lectures and seminars during five weeks, one week per phase. The students work on a project in groups investigating train delays for a fictious company called Easy Train. All groups get different data files that have been prepared to include different hidden root causes of delays. It has been set up so they will use as many tools in the DMAIC phases as possible. Also, the teachers know the hidden root causes the students are supposed to find.

Once they start their real projects at real organisations in the Six Sigma project course, they are told "*Now you know Six Sigma, now you need to use it in reality. This course is really on Project Management*." The truth is that they do not fully understand all about Six Sigma yet, but they are well prepared to use it in a real project. Otherwise, it would not work, as we saw in previous experiences. The real projects are carried out at real organisations during the autumn semester. Needless to say, the teachers do not know the hidden root causes but if needed help the students to find them. The projects were set up during the spring semester by the examiner, who previously worked as a Six Sigma Master Black Belt at major companies, together with industry companies and official organisations.

In the end of the Six Sigma project course the students will be certified as Six Sigma Green Belts. They will also get university credits and grades, where the grades are somewhat influenced by the feedback from the organisations where they express whether the projects have fulfilled their expectations. During the last two years more types of QM projects, not only Six Sigma, have been carried out in the same way as described above. The other types of projects were Customer Focus, Lean, and quality management system projects.

INTERACTION – EXPERIENCES

The students' view on interacting with industry and public organisations

The Lean Conference

The findings showed that the Lean conference was highly appreciated, and many students described it as interesting, engaging and informative. The students considered that the Lean Conference enhanced their understanding of current issues faced by organisations as well as how Lean is applied in organisations. The content was perceived to deepen their knowledge in terms of enhancing their knowledge on application of specific Lean tools as well as broaden their knowledge in terms of understanding how Lean can be applied in wide variety of contexts. Challenges of implementing lean in organisations, the influence of cultural aspects and the importance of making contextual adaptations was given as examples of the new knowledge gained. Listening to real-life examples was also highlighted as a positive aspect as these examples made the theoretical knowledge gained during the course more concrete and 'come to life'. One student highlighted that it was valuable to get the opportunity to talk to industry representatives since it is not a part of all courses and that such exchange of experience is otherwise difficult for students to take part in. In addition, the content of the conference was also perceived to make the students better prepared for their future professional role both in terms of how to use their knowledge and what future professional directions could be pursued. One student highlighted that this learning activity motivated deep learning rather than surface learning by stating that "*You can apply your knowledge or the things you currently are learning, and thereby find a purpose and motivation for learning it for life and not just pass the course*." One student stated to prefer this type of learning activity over other activities by stating that: "*It is always great to put the things we learn into perspective. Usually laboratory work is meant to do that but talking to managers/employees of organisations that use the very thing we are taught was a better experience and learning way.*" A student mentioned that the placement of the conference at a late stage of the course was good since it could be related to the whole course content. Figure 1 shows boxplots of the results of the student survey.

Although the students who responded to the survey were generally very satisfied, some aspects that could be improved were also mentioned. Technical problems arose with the internet connection, which were considered to negatively affect the possibility to grasp the content and a few students stated to prefer to attend a physical conference. In addition, some students thought that the industry representatives should spend more time answering students' questions and go deeper into the real-life examples.

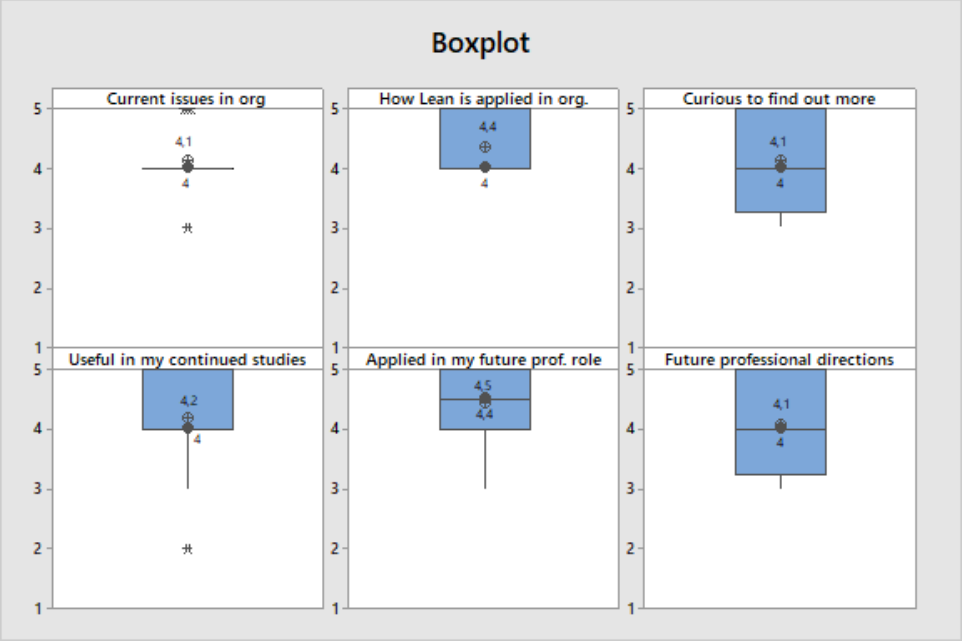

Figure 1. The results of the student survey on the Lean Conference

Note: The filled circle represents the median value and the crossed circle the mean value. The interquartile range box represents the middle 50% of the data and the whiskers that extend from each side of the box represent the ranges for the bottom 25% and the top 25% of the data values. * represents outliers i.e. data points that are far away from the rest of the data points.

Six Sigma projects

Regarding the Six Sigma projects, the students in interviews described that they learnt a great deal, not only about facts related to the course in Six Sigma, but also about project management, how to book meetings, how to describe their work in new ways, and how to solve practical issues. They also described that their learning was to a great extent related to their own behaviour. The courses on Six Sigma, both the basic course and the project course, have had high course evaluations from students during several years, with average evaluation grades between 4.0 and 5.0, often over 4.5, on a scale from 1 to 5 where 5 is the best.

The industry representatives' view on interacting with students

The representatives from the participating organisations, mostly Quality managers, expressed that they were satisfied with the students' work (see numerical analysis below), their competence, and the final results. Most projects were about reduction of defects and cost of poor quality, as well as increasing customer satisfaction and on-time delivery. The representatives emphasized the benefit of having students looking at the company problems from an outside perspective and that they contributed to knowledge sharing within the company. The main problem mentioned in the interviews was the lack of free time to spend with the students, even though it was not as time consuming as they had expected. Other ways of collaboration between industry and the university were also suggested.

In the end of each project the representatives were asked to give feedback on the projects. The feedback was given to the course examiner directly, then, after the course had finished, the feedback was distributed to the students.

In the survey the organisations were asked two questions:

- To which degree were your expectations about the *execution* of the project fulfilled?
  - Answer: Expectations not fulfilled (X), fulfilled (X), or exceeded (X)
- To which degree were your expectations about the *results* of the project fulfilled?
  - Answer: Expectations not fulfilled (X), fulfilled (X), or exceeded (X)

These evaluations were used in the total grading of the project course. The grading scale for the course is fail/3/4/5. If either expectation were not fulfilled it gave the grade 3 (the lowest grade to pass the course), fulfilled gave grade 4, or exceeded gave grade 5. These two grades were two of 25 grades in total, so they had a limited influence on the final grade.

By analysing the feedback grades one can see that

- The organisations are on average very happy by both execution and results with expectations mostly fulfilled or exceeded.
- The grading has low year to year variation. A minor dip is seen during the 'pandemic' year 2020, when the projects were mostly conducted on-line, and off-site.

See figures 2 and 3 below.

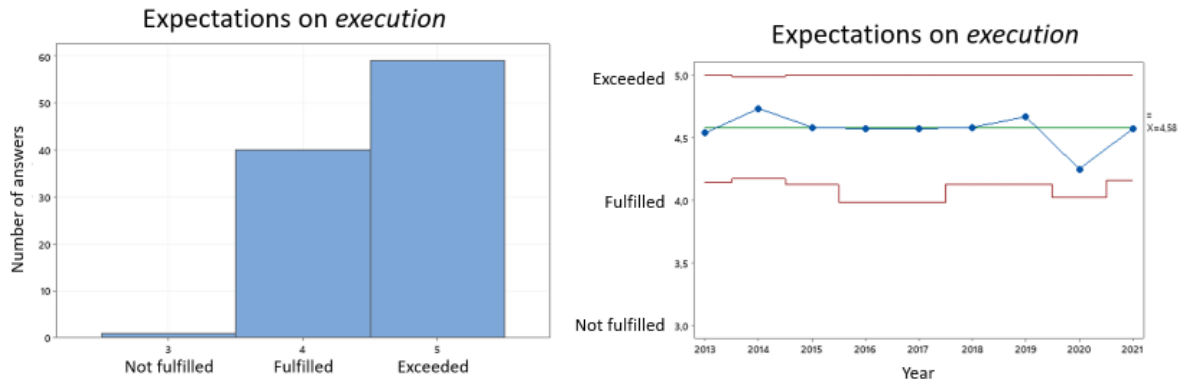

Figure 2. The freqency of the grades (left figure) and the mean grade given over the years (right figure) on Six Sigma project *execution* from 100 organisations. The numbers 3, 4, and 5 represent the grades given for the degree of expectation fullment of project execution.

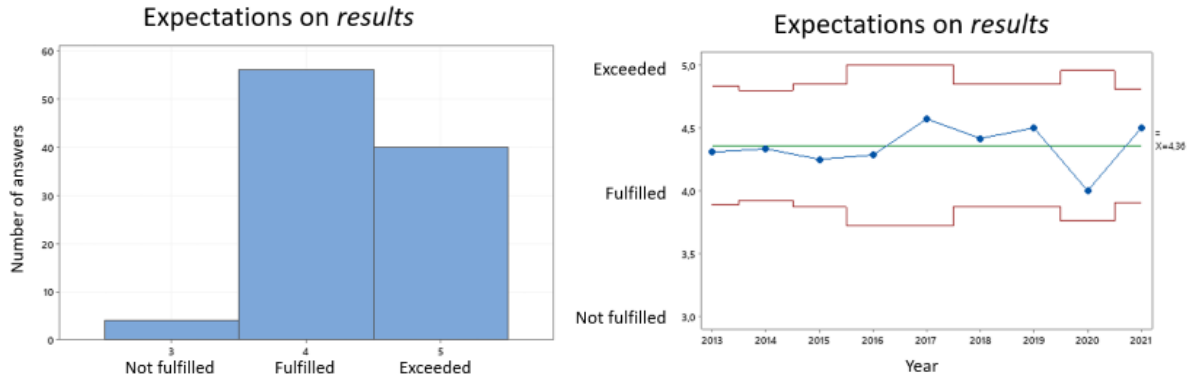

Figure 3. The freqency of the grades (left figure) and the mean grade given over the years (right figure) on Six Sigma project *results* from 100 organisations. The numbers 3, 4, and 5 represent the course grades given for the degree of expectation fullment of project results.

Organising interacting between students and industry and public organisations – the teachers' views

Finding industry representatives that want to present at the Lean conference has been difficult some years due to the presentations being given in English. Many of the industry representatives do not have English as their native language and presenting in English has seemed to be challenging to some. The representatives that do present at the conference often mention afterwards that it is a fun experience and that they are impressed by the insightfulness of the students' questions. Recruitment of industry representatives is facilitated by some representatives coming back to present year after year and if they are unavailable, they usually encourage one of their colleagues to participate in their place.

As previously mentioned, the students' questions submitted to the representatives from industry and public organisations are a central part of the Lean conference. This requires that the students ask comprehensive and relevant questions that can be discussed and that the representatives answer the questions exhaustively. However, sometimes the conference moderator run out of questions when there is still time left in the seminar. To prevent the seminar to end prematurely, the moderator can prepare additional questions in advance for example on topics that was not take up by the students. The moderator may also ask the students during the seminar for additional questions to be discussed. The teachers' experience is that the dynamic between the students and the representatives as well as between the representatives in the panel is often important for the success of the conference. However, this is usually not a problem as this learning activity seems to engage the students.

There is a lot of work for the teachers in the Six Sigma project course – more than regular classroom courses. During the spring semester the teachers are looking for possible projects at companies and public organisations. This takes a lot of time because the organisations are often not willing to admit that they have recurring problems, do not want students to solve their problems and do not understand the Six Sigma methodology. Hence, there is a lot of discussion and convincing to be done. However, the companies that have carried out projects very often return next and following years for more projects. Once the projects have started in the autumn semester, there is quite a lot of work for the teachers doing project coaching and 'toll gating'. Each project has five tollgates for the five DMAIC phases. The purpose of the toll gates is to check that everything is 'correct' and 'complete' in each phase. The results from the project should always be correct and complete, independent of the skills and ambitions of the students. One reason for this is to ensure a good delivery to and maintain good relations with the organisations since they have put a lot of effort and resources into the project and expect it to produce useful results. Another reason is to ensure that the students have a report that is correct if it is to be used as a guide for future Six Sigma projects. The upside is that, based on the feedback from the students, coaching and toll gates support the students learning. The downside is that it takes quite a lot of time for and effort from the teachers.

DISCUSSION AND CONCLUSION

The learning activities aim at familiarising the students with real world engineering issues and prepare them for their future engineering role. The students also put forward the value of meeting with industry and public representatives. Although personal meetings could not take place during the Lean conference during the pandemic, the students normally have the opportunity to approach the representatives in person with individual issues, such as internship. Asking the students to prepare questions before the conference is one way for them to reflect

on the course content and how it fits with reality. This learning process is much more enhanced within the Six Sigma and QM project courses, in which the students for a longer time deal with real world issues with open ended answers. Not having a 'right' answer strongly encourages active learning for the students (e.g. Prince, 2004). However, the teachers have an important role in guiding the students in their problem-solving skills (Hmelo & Ferrari, 1997).

In these courses the students also increase their ability to communicate their results in a real context with stakeholders, which is emphasized in CDIO's Learning outcomes (Standard 2). This learning, along with learning how to run projects and collaborate with representatives for industry or public organisations, are learnings that add to the course context and constitute examples of Integrated Learning Experiences (CDIO-standard 7) where professional engineering issues are combined with other contextually based issues. The value of having contact with and collaborating with representatives for industry and public organisations may also have additional value for students who prior in their education may have had limited external contacts. From a Swedish perspective this is common to strive for and integrate also in early educational phases, but this varies among students depending on where they have conducted their earlier education. Furthermore, the Six Sigma project course demonstrates a Swedish way of work based on values of democracy and pragmatism. The value of integrating real world engineering issues within the university courses relates not only to the students. Also, the representatives for industry and public organisations gain from the outcome of the students' project outcomes. This was clearly shown in the evaluations from the companies that participated in Six Sigma projects where the expectations on execution and result were fulfilled or exceeded for a clear majority of the projects. Also, the lecturers in the Lean conference stated that they were impressed by the students' questions. In addition to value for the students and industry and public organisations, there is also a value for teachers to invite and collaborate with these representatives. It is one way of keeping up to date on current issues within the organisations, what is at stake at the moment and forthcoming issues. This can be an input to ongoing development of the course contents. The idea of evaluating the value for these three groups is further brought forward in Design-Implement Experiences (CDIO Standard 5) where these experiences should regularly be evaluated from students, teachers, and external stakeholders.

Experiences of organising these learning activities include highly positive feedback from students and participating organisations. For the teachers, although it implies a great deal of work, it is a very positive experience that contributes to individual insights and life-long learning.

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