ENGAGING WITH INDUSTRY STAKEHOLDERS TO SUPPORT PROGRAM DEVELOPMENT

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ABSTRACT

Luleå University of Technology (LTU) has adopted CDIO as the framework for developing its engineering programs. At the Department of Civil, Environmental and Natural Resources Engineering, there are two programs focusing on tunnelling, mining and rock excavation. Despite very positive prospects for professionals in the field, the number of students has decreased for the last two years. Further, program content might not reflect recent developments or new requirements in the industry. Therefore, the programs and their courses are taken under renewed consideration. Given the nature of the challenges facing the programs, it is in this case particularly important to inform of the planned development through a dialogue with stakeholders. Stakeholder dialogue is also a key feature of a CDIO curriculum development (CDIO Standard 2). This paper reports on a process of engagement with industry representatives, initiated through a meeting to discuss the competence of newly graduated from LTU as well as the future needs in the industry. The input will make it more visible what programme and course development work needs to be done in the nearest future. A continued support and feedback from the industry is warranted during the programme development.

KEYWORDS

Stakeholder dialogue, program development, learning outcomes, Standards: 1, 2.

INTRODUCTION – STAKEHOLDER DIALOGUE IN PROGRAMME DEVELOPMENT

The CDIO approach for engineering education reform advocates the use of stakeholder input in the programme development process. CDIO curriculum development starts with the recognition that students need a high level of preparation for professional engineering practice (Standard 1). Therefore, program level learning outcomes should express a deep working understanding of disciplinary fundamentals, as well as personal, interpersonal and professional engineering skills – and these program level objectives should be validated with the stakeholders of the program (Standard 2).

The term stakeholder originates from business science literature, where it refers widely to "*any group or individual who can affect or is affected by the achievement of the firm's objectives*" (Freeman 1984, cited in Jongbloed et al., 2008). The stakeholders of an engineering program include at least the students, society in general, teaching faculty, government and taxpayers, employers in industry and the public sector including universities themselves. It is however often a delicate challenge to get input from these groups.

Engaging stakeholders is never a straight process of “taking orders” from them. The relationship between stakeholders and universities can be characterised as *loose coupling*, implying that the university is responsive to its stakeholders while fully preserving its own identity and logical separateness (Weick, 1976). After collecting input on its stakeholders’ interests, the university has to evaluate and select its own direction among the various wishes from a chorus of voices, including students, employers, society, the university itself, and the research community. It is also a matter of balancing short-term and long-term interests. Finally, the aims that the university decides upon must be realistic to achieve within the available time and resources, such as faculty competence.

BACKGROUND TO THE CASE

Programs in tunnelling, mining and rock excavation

Luleå University of Technology (LTU) has adopted CDIO as the framework for developing its engineering programs. At the Department of Civil, Environmental and Natural Resources Engineering, there are two programmes with a focus on tunnelling, mining and rock excavation. One of the programmes is a five year national MSc in Civil Engineering, with specialisation in Soil and Rock Engineering. The other is a two year international MSc in Civil Engineering, with specialisation in Mining and Geotechnical Engineering. The majority of the courses are shared between these two specialisations, and therefore the students graduating from these programmes have similar knowledge and skills within the area of Mining and Geotechnical Engineering, i.e. constructing and excavation in rock and soil. The graduates often become consultants, building entrepreneurs, buyers of services, and mining engineers.

LTU as a technical university has a long tradition of applied research and is therefore a university with close collaboration with the industry. Hence, within the field of mining and tunnelling there are continues dialogs with the industry regarding research issues and future aspects. The faculty often assume what content should be included in programmes and courses based on issues within research. Despite continues discussions and close collaboration it is seldom that education, courses and programmes are deeply discussed at meetings with the industry. At present there are compelling reasons to take the programs and their courses under renewed consideration. Despite positive prospects for professionals in the field, the number of students in the programs and specializations has decreased for two consecutive years, as shown in Table 1.

Further, the program and course content has changed relatively little in the last 10-15 years and might not fully reflect recent developments in the industry. Given the nature of the issues facing the programs, it is in this case particularly important to inform the planned development through a deeper dialogue with stakeholders.

Table 1. Number of students registered in last years of their study 2012 – 2017.

Program	2012	2013	2014	2015	2016	2017*
International MSc in mining	1	5	7	11	8	5
MSc with specialisation in Soil and Rock Engineering	17	24	22	27	18	8

* Number based on registrants in the year before the last.

Evaluation of the programmes and courses

The university has implemented a new pedagogic concept (Wikberg-Nilsson & Gedda, 2013) and uses by that a model where each programme every second year do a self-evaluation regarding ten different areas (which are similar to the CDIO standards). The self-evaluation performed for the national civil engineering programme as well as the CDIO-evaluation showed that Standard 9 and 10 was graded with low values (1-2). To successfully implement CDIO the university, the faculty responsible for the programme and its courses need full commitment (Chuchalin et al., 2015). It is therefore very important to involve the faculty in the programme, both in the on-going CDIO implementation and in the continuous work. This regards the whole programmes and not just certain specializations. At the moment there is a lack of active and shared communication between the faculty and the programmes.

Based on the evaluation we get input on course level from the students at the programmes. A standardised questionnaire form has been developed and is used in all courses at LTU. The questionnaire form consists of both multiple choice questions and free-text questions. The examiner and the programme responsible receive compiled data from the questionnaire for evaluation. The course evaluations are then discussed at programme council consisting of teachers, programme students and sometimes industry representatives. The programme council meets four times per academic year. The current students focus on content and execution of courses and what was good or bad from the student perspective, i.e. workload, quality of lecturing, meaningfulness and feasibility of assignments, course structure, timely availability of information etc. They are seldom able to evaluate the quality of the courses from the perspective of their future working life. Therefore, the evaluation process is more relevant for short-term improvements of individual courses and to some extent the overall programme. It is necessary to implement other forms of communication between stakeholders and the programmes.

This paper will report exclusively on activities to engage with one stakeholder group, the employers. It is just as important to understand the views of other stakeholders, not least the students, however this is outside the scope of this paper.

METHODOLOGY FOR COLLECTING INDUSTRY STAKEHOLDER INPUT

In order to get input from employers, a one-day meeting was arranged at LTU in October 2016 by the head of undergraduate education and the program director (authors one and two). 11 representatives attended (16 were invited) to comment on the competence of graduates as well as the future needs in the industry. There were representatives from the mining companies Boliden and LKAB (among them authors four and five), the Swedish and Norwegian road and railroad administration, and consultants (Ramböll, WSP, Industrial Management Solutions and Nitro Consult). Of the 11 employer representatives, nine were also themselves LTU alumni of one of the programs under discussion. One alumn had graduated from LTU within the last 5

years, two alumni within the last 10 years and hence the others more than 10 years ago. Also present was a CDIO expert (author three).

Structure of stakeholder meeting

The meeting was separated in four phases, starting with (i) an introduction and presentation of the current setup of the program and its courses, then a (ii) group work, followed by (iii) joint reflection and (iv) an introduction to CDIO and final reflections.

In the group work the representatives were divided into three rooms for a focus activity for almost two hours. The participants were asked to spontaneously express the desired competence and skills of the graduates and to describe the circumstances within their part of the industry on which they based their views. The participants were given the following prompts:

When it comes to new graduates

- *What usually works well…*
- *What we wish for…*
- *When there are problems it is often about this…*

Thinking 10-20 years forward

- *What will be more important to learn at university…*
- *What will be less important…*

The group facilitators (the three first authors) held a low profile in the discussion, mainly capturing the discussion in detailed notes. After each participant had presented their views, they kept discussing and comparing with each other, but they were specifically instructed that they did not need to reach any agreement, as the program was interested in the full diversity of the views.

After a lunch break, the facilitator of each group reported preliminary results from their notes, followed by a joint reflection in plenary, about one hour discussion to compare and analyse the input. Finally, a brief presentation was given on the CDIO approach to engineering education development. The final discussion came to focus on the appropriateness of CDIO to address the particular needs that had been delivered earlier, and on the conditions for change at the university. Also, the issue of industry collaboration to purposefully support the programme development was raised.

In the following, we present and discuss the results of the meeting, followed by reflections on the format for the meeting as a stakeholder dialogue activity.

RESULTS

Comments on new graduates

The stakeholder representatives had many positive things to say about LTU graduates. Typical comments were that they have the right curiosity and appetite for learning, and a self-driven and independent approach. The seven month internship at a company was seen as an important factor to strengthen this attitude, as it seems to help students see themselves in the role of engineers. The stakeholders confirmed that industry needs self-driven employees who can actively find their answers and

solutions to problems, in a structured and cooperative way. Graduates were also commended for their good basic knowledge. Some suggested that their specific knowledge could always be deeper, or more relevant for a certain branch of the industry, but in the end there was strong agreement that such specific demands should never set the agenda for the education. The general viewpoint can be illustrated by this quote:

> *"We do not expect a graduate to be a 'finished product', but a person who we can continuously support in their development for our specific activity."*

The industry representatives also identified some main issues that need to be considered in the program and that they thought should be strengthened. The main suggestion for improvement can be summed up as "holistic approach". While the graduates are often good at handling a specific technical issue, they had problems to see them in the light of the process as a whole. There is a risk of sub-optimization, when the engineer fails to understand their part of the work in an overall view. Further, most decisions are not solely based on technical considerations, but they may also be affected by legal aspects (e.g. contract relations), considerations for time, cost, safety, environmental impact, etc., or even just the need for predictability in relation to such issues. If the engineer has an overly narrow view on their role, it can also have consequences for the ability to communicate and cooperate with others who are involved in the process.

One remark shows how important it is to introduce the holistic view early in a programme, since students will benefit already from the beginning and throughout their whole education. With improved initial understanding they can take on the courses in a better way:

> *"The sooner a student can see the whole picture, the better their understanding, and the better their motivation in the remaining courses."*

A related issue is that graduates seem to have something of a hang-up for finding the exact one right answer, in a dualistic or black-and-white sense. It was suggested that the students' long experience of having their work evaluated by teachers, for instance in exams, contributed to this "right answer" attitude. The industry representatives were in agreement that new graduates need to be more open for different ways to handle a problem. In most cases, engineering is a matter of weighing different alternatives and finding a reasonable level for the solution, rather than a perfect one. This is also related to students' ability to handle uncertainty, and making assumptions and estimations:

> *"Rock mass investigations are important for all engineers in the field. It's a general skill, no matter where you end up working. But they also have to know how to interpret the data, and understand the uncertainties and how the assumptions play in. It is an awesome judgment sport!"*

The industry representatives agreed that the courses should help students make more out of the cases, and see them less as a quest for the right solution, and more as general examples, to understand principles. This can take a larger role in the programs. As an example, in the planning and design of different constructions in rock there will be distinct differences in requirements, depending on what type of construction is built. A drift in a mine may only need to last a few months, while a railroad tunnel must not leak water for 120 years – and the extreme case is a nuclear waste depository built to last 10-100 000 years. While such projects have still much in common, these different demands result in different requirements and students

must be able to adapt their thinking. The problem is that when students have only encountered one of these types of cases, they are not prepared to think differently. To optimize the design of a construction students also need a wider understanding of its function, the working environment, safety, impact on surroundings etc. Therefore, students need to experience a variation of requirements on underground constructions, and they need support to reflect, in order to understand both similarities and differences.

Certain aspects of courses are very much appreciated by the industry representatives, as they help the students develop a wider thematic understanding. Many of the courses in the programs include assignments and pre-defined technical problems that are linked to reality, e.g. by using real data, and in some courses students spend some time at site solving problems for the industry. Still, the stakeholders identified the need in the programs to highlight even more ill-defined and complex problems, containing e.g. legal, economical, ethical, and environmental aspects.

The industry representatives also noted that students use numerical modelling to solve problems in many courses. For some students, the focus of the education seemed to have created unrealistic expectations on the workplace, as they had expected the work to be all about making numerical analyses, when in fact this was a relatively minor part of the work. Similar to the remarks above, the stakeholders commented that graduates could easily use modelling tools, but not always analyse the results and see if they were realistic or not. Hence it seems necessary with more training and guidance on how to use rough estimations and verification of results, and much more reflection on what they are doing and why:

> *"There are so many sophisticated tools and methodologies that people stop thinking!"*

Regarding students' skills the employers commented that engineers always work in projects, ranging from one person to hundreds involved. It is therefore important to develop students' skills in planning their own time, and the ability to coordinate a project.

> *"In the workplace, when you work with technology, it is all about people! You need to learn how to work with others already in the education."*

The life-cycle costs need to be considered in order to get a sustainable economy in underground constructing. Being costs-conscious and able to relate project and results to economy was something that the stakeholders suggested should be better integrated in the program courses. Instead of just determining and suggesting the amount of rock reinforcement for a tunnel, to name an example, the students should be able to also assess the resulting safety in relation to its costs.

What to learn for future mining and tunnelling

The industry representatives saw in particular the supply of engineers as a great challenge ahead for the industry. There are many large-scale projects in the pipeline, including increasing maintenance needs, at the same time when many engineers are about to reach retirement age. This also highlights the need for transferring knowledge between experienced engineers and newly employed graduates. The most precious abilities that the old engineers have gained through long experience, were precisely the holistic view, discussed above. This is an area where the narrow conception of engineering really has an impact.

The developments within the industry seem to only emphasise even more the wishes expressed above for the education. Both within tunnelling and mining the environmental issues, such as vibrations, noises, ground subsidence or settlements, have become more important in the last years. The legal aspects are already, but will also become more, important in the nearest future, especially within mining. To become resource efficient, and contribute to sustainable underground constructing, one needs to understand the context of the problem and realize that it is not just about the technical issues.

Students need to be aware of both the issues and problems that exist today but also which are the future issues to consider. Regarding the future, in a 10-20 years horizon, the main differences compared to today are likely to be (i) increased automation, (ii) increased depth of constructions and (iii) more focus on sustainability. The vision from the industry is to place fewer workers in the production area (in e.g. Nikolakopoulos et al., 2015) and make measurements of the rock mass less subjective. This requires an automated environment where machines, instead of humans, perform the monitoring and production. When more automation is introduced, the generated data needs to be analysed by our future graduates. With deeper mining the complexity of many problems will increase, such as logistics, more seismic events, ventilation on demand, rock mass stability, increased production costs, etc. More standardardized solutions and design is likely to increase in the future in order to develop sustainable rock excavation. As a result of this the type of rock reinforcement and installations are pre-defined. Hence graduates needs to for instance be able to optimize the amount of reinforcement.

Other issues raised regarding the future was that the maintenance of rock excavations is likely to increase, given all the tunnels, mines and waste depositories that have been excavated during the 1900s and 2000s. Hence our graduates must be able to give suggestions on rehabilitation of underground constructions. For future constructions and in order to minimize the need of maintenance our graduates should consider the life-cycle costs.

Discussion and suggestions for industry-university collaboration

It can be a difficult task for representatives to speak for a wider group than to describe their own needs. In addition, it is often necessary to also consider underrepresented or absent groups. For instance, while present students can be directly represented, it is harder to hear the voice of prospective ones. In many cases we would want to better understand the perspectives of groups that have presently not been sufficiently attracted to engineering education. A programme may want to ask not only "*who are our students?*" but also "*who should be our students?*" (Jongbloed et al., 2008). As another example, it is easier to get access to the perspectives of the presently dominant employers of the programme, than to understand the needs of new or future forms of work. This may have consequences for innovation and entrepreneurship, as it may for instance require a slightly different set of competencies to work in smaller companies, or in start-ups, than in large established companies or authorities.

The industry representatives identified several ways in which the sector could support university education. Among the suggestions were:

- Providing external lecturers. Their role should, above all, be to provide real cases and give a realistic picture of the holistic view, discussed above. They can also help with a view on future developments in the industry. However, it is important that the course responsible is available for dialogue about the

place of the guest lecture in the course and the program, and its role in preparing for professional practice, and also be present at the lecture!

- Course responsibles were warmly welcomed to practice in industry, at least for a few days every year. They can be arranged as visits for shorter or longer time, or even through consultancies. The main purpose is to stay informed about the present state in the industry and how our field work in practice.
- Student internships are considered extremely valuable, and should be compulsory for all engineering students.
- Study trips and field work are also valuable, and should be increased if possible. There are so many sites with on-going and interesting projects, and students should visit both the office and the site. We should also discuss methods for making study visits more active, and to build in reflections to interpret these experiences, to maximise learning.

CONCLUSIONS AND NEXT STEPS

Collecting and analysing stakeholder input, and making informed decisions on the programme objectives is only the first step, as expressing program goals in a document is not enough to develop an education programme (CDIO Standard 2). The next step in the program development is to assign the program learning outcomes to the course level parallel with the implementation of constructive alignment during 2017-2018. Thus, the responsibility of each course is expressed as course learning outcomes, will make the function of each course in the program explicit (CDIO Standard 3). To reach an integrated curriculum we need an active and shared communication between the faculty and the courses. The extent to which graduates will actually fulfil the stated program learning outcomes will then hinge on:
(1) the connection between courses and programs – that the course level outcomes taken together measure up to the intended program outcomes, and
(2) the fulfilment of each course to teach and assess students according to its intended learning outcomes – also known as constructive alignment (Biggs & Tang, 2011).

We should build upon our strengths in courses and programmes, and improve by making changes where we are lacking. Connected to that and based on the comments from the industry, we need to use more real cases in our programmes where one right answer is exception and where the students have the possibility to weight different alternatives based on for instance method, technology, life cycle costs and safety. This should be implemented as integrated learning experiences (Standard 7) in order to make the disciplinary knowledge come alive through application, also to authentic problems and situations. Students also need to be better prepared for analysing different kind of data in order to realize if they are realistic or not and which are the most important to consider. Since collecting, verifying and analysing data is an important focus and part of the content in several courses, this could be discussed in a thematic workshop for the faculty.

The investigations of a rock mass, which was highlighted as generic skill by the industry, have been improved and changed regarding requirements and techniques during the last 10 year. This is also the case for all steps within the process of building underground. The teaching faulty might not be fully updated in the process and what engineers do in such investigations. One suggestion from the industry was to have teachers as trainees for a limited time period. This is a clear action regarding faculty competence (Standard 9).

A part of the senior faculty at the research subject mining and rock engineering is taking a pedagogic course at LTU, closely linked to CDIO. Some examiners in the programmes are therefore aware of constructive alignment and have implemented it in their courses. However it has been obvious that written exams are the most common assessment method within the programmes together with written group assignments. The aim is to reach a program where all courses have a purpose, are arranged in a purposeful sequence, support each other and integrates professional skills, personal skills and interpersonal skills (Standard 2 and 3). Based on the comments from the stakeholder meeting and on-going developments work the program goal and objectives will be revised.

Employers and alumni of the mining and tunnelling related programs at LTU show a great interest in the on-going work with programs and courses and are willing to continue in dialogs and meetings in the future. Further discussion with the mining company LKAB was held in November 2016 with special focus on the course “open pit and underground mining methods”. At that meeting, the representatives from LKAB suggested that the program responsible should arrange a whole day workshop during 2017 in order to discuss more in detail all courses related to mining. A continued support and feedback from the industry is warranted during the programme development. This could be done by yearly thematic workshops, arranged by LTU, and by board meetings (Standard 2). The result and comments from the stakeholder meeting needs to be further communicated and discussed with both students and faculty.

In October 2017 a faculty development course will be held by and arranged in Luleå. It will be arranged with university partners from Luleå, Madrid and Clausthal, Chalmers, Delft and Limerick. A faculty course where presentations about engaging stakeholders as well as course and programme development work within mining related programmes will take place. At the event industry partners and research institutes from Sweden and Ireland will attend. The event will contribute to Standard 9 and 10.

ACKNOWLEDGEMENTS

We would like to thank the industry representatives who very generously shared their insights and time with us.

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