Preprint version. Final version appeared in International Journal of Sustainability in Higher Education, 2012, 13(3), pp 305-320: http://dx.doi.org/10.1108/14676371211242607

Are we educating engineers for sustainability? Comparison between obtained competences and industry's needs

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Abstract

Purpose – The aim of this paper is to provide input to revisions of engineering education curricula to better meet the needs of competences in sustainable development (SD) within industry. The objective is to present an exploratory case study that looks into what competences in SD that are focused on in engineering curricula at Chalmers University of Technology (Chalmers), as indicated by course content and questionnaires to students and alumni, in relation to the competences that representatives from Swedish companies claim that they need from engineers. The assessment sets out to answer the following questions: *What competences do students obtain in the educational programmes? What competences do the companies need? What is the gap between what is obtained and what is needed?*

Design/Methodology/Approach – The content in 70 courses in environment and SD were characterized and quantified using course document text analysis. Additionally, two questionnaires were sent to students and alumni at Chalmers, and interviews and focus group discussions were conducted with representatives from 16 Swedish companies and five organizations.

Findings – Industry demands a broader range of competences in SD amongst engineers in general than what is currently provided. 35 % of alumni claim they encounter sustainability issues from sometimes to daily in their work. However, only half of them believe they possess enough competences to make decisions from a sustainability perspective. Quantity, coverage and the level of integration in the educational programme all appear to be important for the students' perceived competences on SD and for the importance that they put on achieving SD.

Originality/value – Earlier research has reported on how to further develop the idea and design of education for sustainable development (ESD), and on competence needs in general. Few attempts have been made to assess industry's needs of competences in SD. This paper sheds light on how engineering universities educate for SD and benchmarks this to industry's needs in an exploratory case study, using Chalmers as an example.

Keywords – Higher education, sustainable development, engineering education, competences, Swedish industry

Paper type – Research paper

1 Introduction

The concept of sustainable development (SD), and the demands that this puts on individuals and professionals, is constantly evolving. It is therefore vital that educational institutions are flexible regarding the competences related to SD that they aim at providing to their students. Previous research focuses on the design, learning outcomes and general competences of education for sustainable development (ESD), as well as the quality of present ESD (Hanning & Priem Abelsson 2010). Svanström *et al*. (2008), for example, discuss learning outcomes for ESD and emphasize the importance of skilfulness in a discipline as well as systemic thinking competences and an understanding for the complex frame of reference when dealing with SD. Moody & Hartel (2007) looks into what is known as Environmental Literacy Requirements (ELR) and shows that, when

implemented in education, this increases the students' knowledge on and concern for environmental issues. They state that the best outcome is achieved when the entire university curriculum is infused with relevant education in relation to ELR. This also avoids environmental courses becoming another add-on to the curriculum (Moody & Hartel 2007). Fokkema *et al*. (2005) mention that SD is a transdisciplinary playing field in which engineers cooperate with other disciplines, thus making it important for engineers to be able to communicate with other disciplines and stakeholders, while at the same time safe-guarding disciplinary quality. Abdul-Wahab (2003) concludes that all engineers can expect to come into contact with environmental problems during their career, hence engineering curricula should include environmental components.

However, there has been little focus on studying industry's need of competences for SD amongst engineers (Hanning & Priem Abelsson 2010). The role and responsibility of engineering universities in societal change processes can be discussed. However, it is reasonable to assume that the competences of the engineers that are delivered to the job market will potentially have a large impact on society and that technical universities therefore may play an important part in societal change towards sustainability. The research presented in this paper is part of an effort to critically review the activities, visions and plans of an engineering university in terms of competences for SD in education and to benchmark that against what society needs in the short and in the long term. In the exploratory case study presented in this paper, course contents, and statements from students, alumni and company representatives are used as indicators of competences obtained by engineering students, and statements by alumni, company representatives and representatives of different organizations are used as indicators of industry's need of competences in SD.

The aim of this study is to contribute to the quality improvement and long-term strategic development of ESD in engineering education curricula. The assessment focuses on three main research questions: *What competences do the students obtain in the educational programmes? What competences do the companies need? What is the gap between what is obtained and what is needed*?

1.1 Education for Sustainable Development at Chalmers University of Technology

Chalmers University of Technology (Chalmers) is the second largest technical university in Sweden. Chalmers has 11,000 students enrolled in programmes ranging from three-year BSc in engineering programmes and five-year MSc in engineering and architecture programmes, to two-year MSc programmes and doctoral programmes (Chalmers 2011). Since 1985, all students enrolled in a five-year MSc programme at Chalmers should have had a course in environmental science during their first three years of study. Since 2003, this course requirement is described as: all students in five-year programmes (since 2007 also for the three-year programmes) should do 7.5 higher education credits (ECTS) of course work in environment and SD during their first three years of study in order to attain an engineering or architectural degree at Chalmers (Chalmers 2010).

The requirement is today met by all 29 different educational programmes. As a help to programme coordinators and responsible teachers, a guiding text on ESD has been devised in which competences that should be obtained are described (Chalmers 2009a). The programme coordinators are responsible for planning programme curricula, also in terms of the requirement on environment and SD, and thus, different programmes have developed different approaches to how education in environment and SD should be addressed. Some programmes offer one full 7.5 credit course in environment and SD, while other programmes offer this as integrated parts of other courses. Yet other programmes offer a comprehensive course on environment and SD in combination with environment and SD issues integrated throughout the programme and hence the total amount of credits in environment and SD varies between programmes.

2 Method

Three main methods have been used to answer the research questions; an *analysis of course content using course document text analysis* in 70 courses at Chalmers, *semi-structured interviews and focus group discussions* with 16 Swedish-based (both domestic and international) companies and five different organizations (The Natural Step, the Swedish Defence Research Agency, the Swedish

National Agency for Higher Education, the Association of Swedish Engineering Industries, and the Swedish Association of Graduate Engineers), and two surveys in the form of *questionnaires* sent to Chalmers' students and alumni. By using different methods, each method providing answers to more than one of the research questions, triangulation of the results has been possible in order to reveal commonalities and differences between results obtained from different methods. In this study, the triangulation of methods mixes qualitative and quantitative methods which make the study more comprehensive (Neuman 2011).

In this paper, the word 'competences' is used for learning outcomes that the students should possess (and be able to show) when they have passed a course or a whole educational programme. These competences are of different character and can sometimes be very difficult to evaluate or even discuss. Since very few of the individuals approached in this study have any kind of education in pedagogy, the communication around competences has been hampered by a lack of understanding of actual competences or learning outcomes. Therefore, competences often had to be discussed in terms of specific course content or abilities to use different tools. In the Swedish degree ordinance, competences are divided into *knowledge and understanding*, *skills and abilities*, and *values and attitudes* (Swedish National Agency for Higher Education 2011). In general, competences from the first two groups are generally considered easier to evaluate than competences from the last group. In the present study, only indirect indicators of competences have been studied. It has been assumed that the content of courses, analysed from course document texts has a strong relationship to achieved competences after the course, which is probably a strong exaggeration of the efficiency of the teaching and learning in the courses. Indicators of learning outcomes in terms of knowledge and understanding can be, for example, the theoretical content in courses while indicators of skills and abilities can be tools and methods that are practiced in the courses. Indicators of learning in terms of values and attitudes can be opportunities for reflection on sustainability impacts of technology in courses. The reasoning behind what educational element that leads to what competences is in this study based on the authors' judgements, and hence highly subjective. No descriptions have been found in literature on how this can be done.

2.1 Methods used for studying obtained competences

The course content in 70 courses on environment and SD at Chalmers (as of 2009/2010) was analysed and quantified using all texts relating to the courses that were made available by the teachers to the students through the student web portal. The 70 courses were selected partly based on statements by programme coordinators on how the course requirement of 7.5 credits on environment and SD is fulfilled, and partly based on how courses are tagged in the student web portal by a 'Theme Environment' label. Most of the analysed courses had an extensive amount of material available, including lecture slides and lecture notes, and course and project memoranda.

A scale for categorizing course content and course activities in terms of the intended depth of learning was created, inspired by different assessment frameworks available in literature (Hanning & Priem Abelsson 2010). The CDIO (conceive, design, implement, operate) approach, developed for technical universities, utilizes a three-grade scale (introduce, teach and utilize) to characterize the intended depth of learning (Crawley et al. 2007). Bloom's taxonomy of educational objects is based on six categories: comprehension, application, analysis, synthesis and evaluation, and can also be used to categorize educational objects based on the intended depth of learning (Bloom 1956). It should be noted that today, the different levels in Bloom's taxonomy are often seen as different types of competences rather than different depths of learning, a specific level thus not necessarily requiring fulfilment of all underlying levels. Yet, the levels provided inspiration to the present study. Impressions from the two systems were used in creating a pragmatic five-grade scale consisting of the levels: course content corresponding to up to one lecture (1), course content corresponding to a couple of lectures, or a recurring topic (2), course content corresponding to a large amount of lectures and/or a project (3), course content assigned to an entire course (4), and content assigned to an entire bachelor or master thesis (5).

For categorizing course content into different areas, the taxonomy of Segalàs *et al*. (2008), using ten different categories, provided input, but in this study, an eleventh category relating to communication skills was added after the company interviews had been performed (Hanning & Priem Abelsson 2010).

However, no course content appeared that could be put into this category. Also, some of the categories used by Segalàs *et al*. (2008) where adapted to better fit the understanding of the authors and the course content found at Chalmers. The eleven different categories used were; *environment*, *assessment tools*, *resources*, *green technologies*, *economic aspects*, *management*, *stakeholders*, *politics and policies*, *social impacts*, *values*, and *communication*. Almost 200 different course topics relating to SD were identified, categorized and quantified according to these categories. For more information on which topics that relate to each category or categories, see Hanning & Priem Abelsson (2010). In the results section of this paper, the eleven different categories have been further aggregated into three categories: *environmental (environment, assessment tools, resources, green technologies)*, *social (social impacts, values)*, and *economic issues (economic aspects, management, stakeholders, politics and policies)*. The decision on what categories that were covered in the courses was based on the comprehension of the authors. Communication did not have to be included in any of the three categories since this was not found in any course material analysed. However, it must be noted that a topic can be covered to some extent in a course and still not be visible in the course texts. In a study regarding Cardiff University's curricula, and their contribution to SD, Lozano & Peattie (2011) utilized a fourth category named *crosscutting themes* in order to address SD issues that go beyond any of the three other categories. In order to address crosscutting course content in this study, some course content was assigned to several content categories, thus eliminating the need for this fourth category.

A self-completion questionnaire was sent to all third-year students enrolled in a five-year engineering programme at Chalmers in the spring of 2010. Surveying all third-year students meant that most of them had participated in the mandatory courses on environment and SD, making it possible for them to reflect on the obtained competences. The questionnaire was designed with close-ended questions (Bryman 2004). The questions aimed at providing answers on students' insight into the concept of SD, and on the relevance that they attribute to SD. The answers were analysed using an online survey tool, where groups of questions could be analysed together in order to correlate the results from different questions to each other. The answers were also analysed in light of the findings from the course content analysis in order to triangulate results from the different methods. The student questionnaire was sent to 2440 students, out of which 650 students responded, yielding a response rate of 26.6 %.

A questionnaire was also sent, in the spring of 2010, to a selection of Chalmers alumni that had graduated in 2006. The decision to approach this particular group of alumni was based on that the Communications and Marketing office at Chalmers sent an alumni survey to this group in 2009 (Chalmers 2009b) to assess the alumni opinions regarding their work in relation to their previous studies at Chalmers, and also since a similar group of alumni was used by Dahlberg (2009) when assessing Swedish engineers' opinions about their careers. This survey population was chosen for the purpose of re-using some of the questions from the previous surveys to see if the responses to the same questions would differ when used in different surveys in two consecutive years. This questionnaire was also a self-completion questionnaire with close-ended questions, in which the alumni were to reflect on their comprehension of the topic of SD, and how they perceived the education in SD while studying at Chalmers. The alumni questionnaire was sent to 580 alumni, and 136 of these responded, yielding a response rate of 23.4 %.

2.2 Methods used for studying competence needs in industry

Semi-structured, audio-recorded interviews and focus group discussions were used to provide input on Swedish industry's competence needs in SD amongst engineers. The interviews and the focus group discussions were conducted with one or more interviewees from 16 different companies and five different organizations. In total, 38 people were interviewed or participated in focus group discussions at 20 different occasions, 1 to 1½ hours each. A written interview guide with pre-selected discussion areas were sent to the interviewees and focus group discussion participants prior to the interviews. The discussion areas covered company's work with SD, as well as interviewees' view on the future development, their view on education and competences within SD, and on communication around SD within companies. After the interviews and focus group discussions, the recorded material was transcribed and words and descriptions were coded into seven different categories that were selected by the authors during the analysis (Hanning & Priem Abelsson 2010). The seven categories

were primarily based on the previously conducted course content analysis but also on the interview guide and on the outcome of the interviews. The areas were (along with the issue they were to provide input to): *Company structure and view on SD* (on the importance of SD within the company), *responsibility of education and the need for generalists or specialists in SD* (on whether universities or companies should educate engineers for SD, and on which type of engineer that is the most sought after, specialists or generalists regarding SD), *company timeframe and business goals in relation to SD* (on whether competences in SD are needed today, or whether it is only a long-term goal for the companies), *business reasons for working with SD and how companies work with the issues* (on whether or not there is a real need in industry for competences in SD), *company communication and employees' understanding of SD* (on whether or not the engineers need more or deeper competences on SD in order to cope with their daily work), *company view on future SD issues* (on what competences the companies need), and *tools, methods and concepts for SD utilized by the companies* (on what competences the companies need and the gap between the need and competences possessed by new engineers).

The alumni questionnaire used for assessing obtained competences also included questions regarding competence needs. The alumni were asked to relate their previous education in environment and SD to their current work situation in order to say if they needed more or less competences in SD than possessed today, and what competences they were lacking, again utilizing predefined questions. A few years had passed since they went through the educational programme and some changes had likely occurred in curricula after that, which had to be considered when interpreting the results.

2.3 Methods used for analysing the gap between competences needed by industry and competences obtained in education

The course content analysis gave insight into the topics discussed in the courses and the quantity of teaching around each topic. It also shed light on the coverage of categories and subcategories and on the level of integration with other educational topics. The analysis also made it possible to do a comparison between different courses and programmes, e.g. in terms of their inclusion of different SD categories.

The alumni questionnaire studied the alumni perception of what competences they need and what competences they may lack, and therefore directly targeted the gap. The same goes for the student questionnaire that studied students' perception of what they have learnt and what they think they may lack. However, the students cannot be expected to have a complete and accurate view of the competences that industry requires today. Comparing the results from the two questionnaires, however, gave insight into the commonalities and differences of opinions between students and alumni.

The interviews with company representatives from the 16 companies aimed at revealing the companies' opinions on which competences that are important, which level is required and what may be missing today. The five different organizations that were approached were thought to represent a more generic and long-term view of the competences that are required by society than the companies.

The results from the course content analysis and the results from different analyses of the competences needed by industry were also compared to the guiding text on ESD at Chalmers, which describes the competences that should be developed in the students during their first three years of studies at Chalmers. The guiding text on ESD is an important tool for discussing and communicating around competences at Chalmers and it needs to be regularly updated as the perception of what is needed or how it should be expressed shifts. The comparisons were made to identify potential gaps in order to provide input to an updated version of the text. However, the guiding text on ESD includes intended learning outcomes for the students and as discussed earlier, learning outcomes were only discussed and analysed in indirect ways in this study and therefore the comparison was not straightforward.

3 Results

Preprint version. Final version appeared in International Journal of Sustainability in Higher Education, 2012, 13(3), pp 305-320: http://dx.doi.org/10.1108/14676371211242607

In this section, an excerpt of the results is shown with the aim to illustrate how the method has been used to answer the research questions. More results can be found in Hanning & Priem Abelsson (2010).

In some results' presentations, the four educational programmes of engineering physics, chemical engineering, mechanical engineering and computer science and engineering are used as examples. These were selected because they are examples of educational programmes with very different curricula and syllabi in relation to ESD. The chemical engineering and the mechanical engineering programmes both have several courses (five courses) in the curriculum in which SD is integrated to different levels, whereas the engineering physics and the computer science and engineering programmes offer only one course in environment and SD to their students. The response rates of students at these four programmes was also particularly high (ranging from around 45 to 65 % in comparison to the average of 26.6 % for all programmes).

3.1 Obtained competences

Selected results that relate to the first research question, *what competences do students obtain in the educational programmes,* are discussed here.

The course content analysis results show that courses on environment and SD at Chalmers mainly contain course content on environmental aspects, while economic and social aspects are less covered. The amount of teaching on different topics relevant for this study differs greatly between different educational programmes. Social issues are dealt with in very few courses and just as introductory material (level 1 on the five-grade scale).

For the four programmes mentioned above, the course content is strongly tilted towards environmental topics, see Figure 1. The chemical engineering programme exhibits a larger quantity of economic and social topics than the other programmes. Most programmes only covered environment and SD in one course and thus, chemical engineering and mechanical engineering are both rather extreme since they deal with environment and SD in five courses. It needs to be noted, again, that the topics appearing in teaching is not a direct measure of competences obtained by students after the courses.

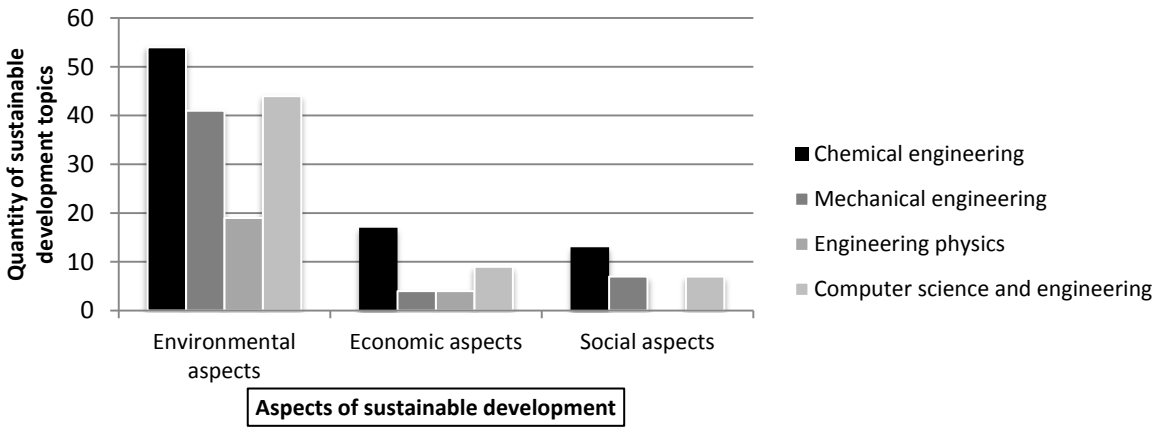

Figure 1: Results from the course content analysis, showing SD topics in four five-year engineering programmes at Chalmers. The quantity on the y axis refers to the amount of teaching within each category as categorised using a special scale developed for this study.

The results from the student questionnaire revealed that students in three out of the four programmes believe they have a good insight into the concept of SD, see Figure 2. The engineering physics students believe they have a lesser insight into the concept than students in the other programmes, which might relate to the results in Figure 1, showing that the engineering physics programme includes a low amount of teaching regarding SD.

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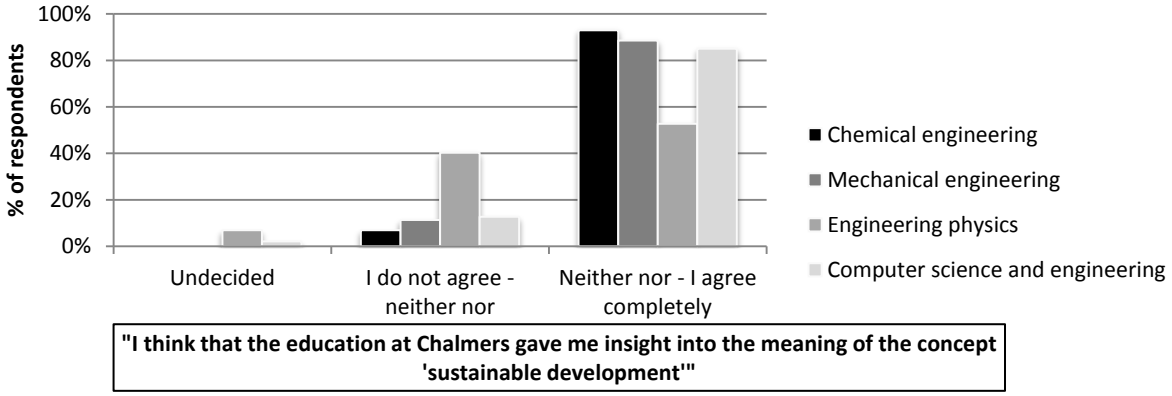

Figure 2: Students' opinions on whether the education at Chalmers gives them insight into the concept of SD - results from student questionnaire in four five-year engineering programmes at Chalmers. The original scale was from 1 (I do not agree) to 10 (I agree completely). Here "I do not agree - neither nor" corresponds to 1-5, and "neither nor – I agree completely" corresponds to 6-10.

Chemical engineering and mechanical engineering students almost all rate SD as highly relevant for their education, while the engineering physics students and the computer science and engineering students rate SD as less relevant, see Figure 3. The results indicate that students attending programmes in which SD has been integrated into more courses put a higher relevance to the subject but there may also be other reasons to this.

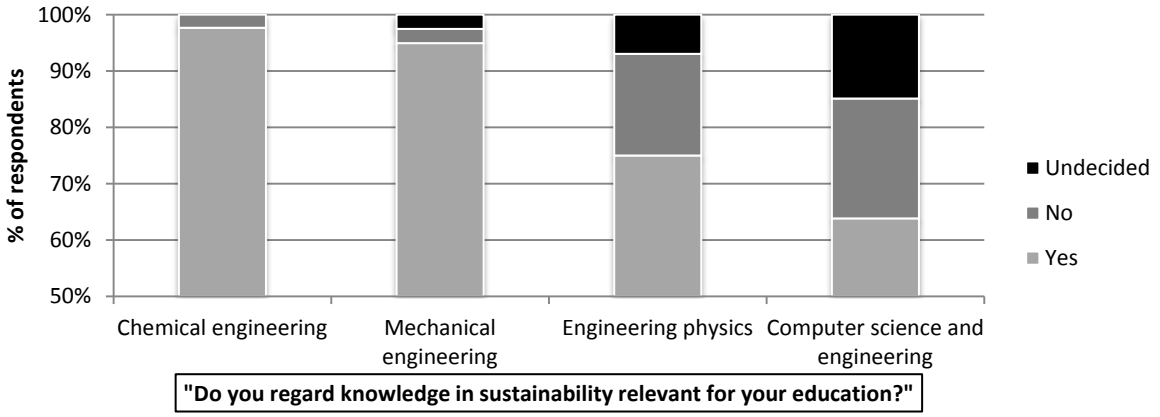

Figure 3: Students' statements on the relevance of SD issues for their education - results from student questionnaire for four five-year engineering programmes at Chalmers.

Quantity, coverage and the level of integration into the programme of environment and SD topics thus seem to be important for the students' perceived competence on SD and also for the relevance that they give to SD in general and in relation to their profession. However, these results are merely indications; no cause-effect relationships can be proven.

The majority of alumni survey respondents, both from this alumni survey and from the previous alumni survey (Chalmers 2009b), 71 and 65 % respectively, say they received very limited or limited knowledge on environment and SD in their education at Chalmers (i.e. from 1 to 5 on the 10-grade scale ranging from "very limited knowledge" to "very good knowledge"), see Figure 4. It is likely that they relate this either to what they believe that they need or to what they believe can be achieved in education.

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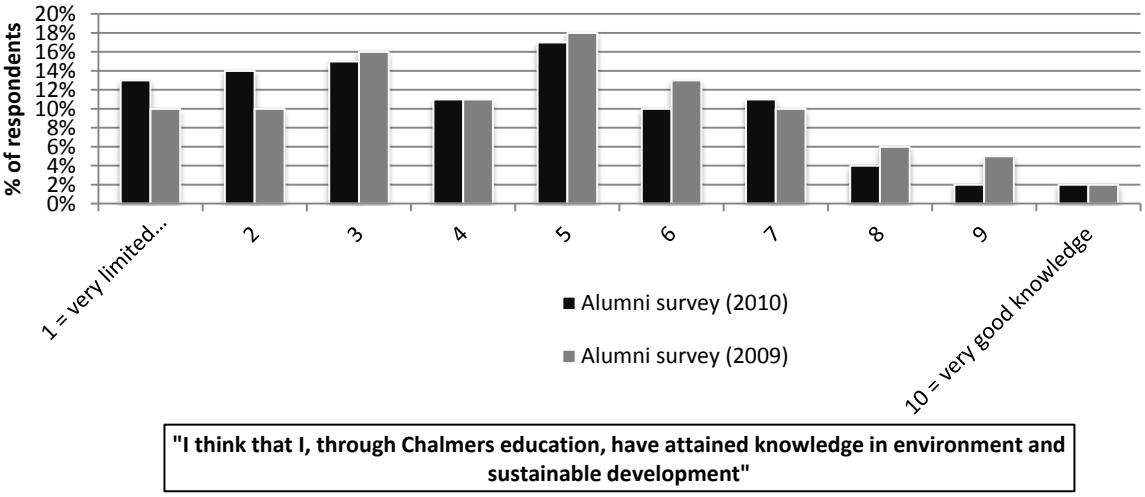

Figure 4: Level of attained knowledge on environment and SD at Chalmers - results from alumni surveys (Chalmers 2009b).

3.2 Competence needs in industry

In this section, selected results relating to the second research question, *what competences do the companies need,* are presented.

The company interviews revealed some important answers to what competences that engineers need in relation to SD. The company interviewees state that they regard environmental issues and sustainable business development as important SD competence areas and that focusing on SD is a business strategy for company survival. Both company and organization interviewees state that to not focus on SD is *not an option*, because the importance of SD will continue to grow in the future. 70 % of the respondents in the alumni survey believe that environmental and SD issues will become more important to their employer in the future.

Company interviewees ask for a higher knowledge level on SD amongst all their employees than today, and claim that their companies also work with a wide range of assessment tools and other methods that require specialist competences. Therefore, they also need students who have taken advanced courses on different methods relevant for working with SD. However, as several company interviewees have mentioned, a majority of the students should still be SD generalist engineers with specialist strength in an area other than SD. Required generic SD competences, as stated by interviewees, relate to underlying reasons to and issues behind SD, but also to the connection to the engineers' future professional role and coming work assignments.

The alumni questionnaire showed that 52 % of the alumni are responsible for SD aspects in their work. Also, 35 % of the alumni claim to encounter SD issues from 'sometimes' to 'daily' in their work, and thus they need competences in SD in order to deal with such issues effectively and correctly, see Figure 5.

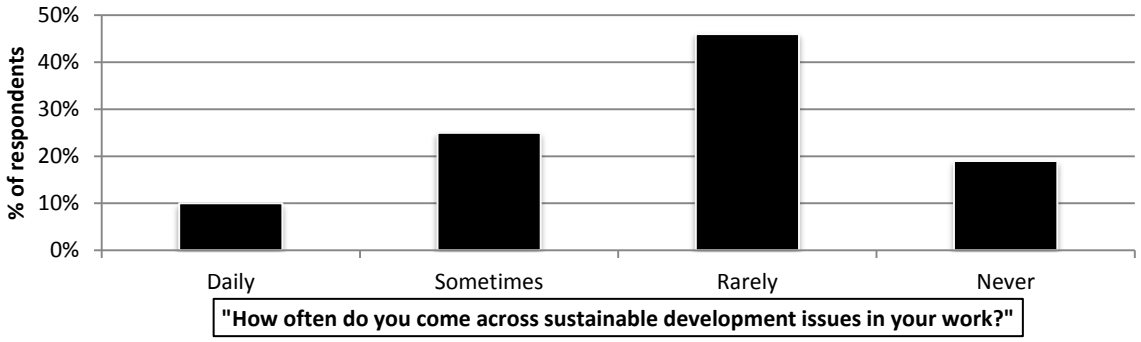

Figure 5: The frequency of encountering SD issues in the work - results from alumni survey

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According to the alumni survey, the most important competence areas when working with SD issues are environmental issues, economics (sustainable business development), and issues related to resources, as can be seen in Figure 6. Communication is rated to be the least important of the suggested areas, which is a result that contrasts to the results obtained by interviewing companies and organisations.

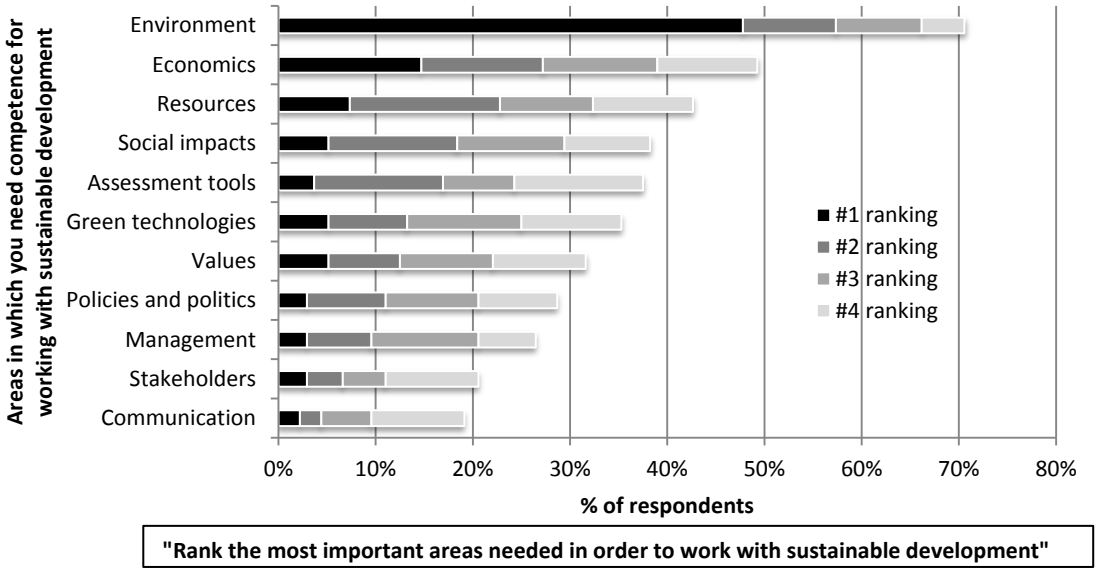

Figure 6: Results from alumni questionnaire on ranking of different areas in relation to competence needs within SD.

3.3 Gap between competence needs and educational outcomes

Results in relation to the third research question, *what is the gap between what is obtained and what is needed,* are presented in this section.

There is a gap between the competences needed to work with SD and the knowledge supplied by education, since many alumni believe they do not possess enough competences to carry out their responsibilities concerning SD issues. When looking at all alumni survey respondents, 32 % believe they have enough competence to make decisions from an SD perspective and 27 % state that there have been occasions when they have not possessed enough competences to deal with SD issues properly. Of alumni that work with SD 'sometimes' to 'daily' (35 %), 47 % state that they believe that they have enough competences to make decisions from an SD perspective. Of alumni that claim to be responsible for SD aspects in their work (52 %), 30 % state that there have been occasions when they have not possessed enough competences to deal with SD issues properly, and only 38 % believe they have enough competences.

The company interviewees state that all engineers need a better understanding of basic issues regarding SD in order to be able to make relevant choices in their daily work. Several company interviewees mention a distinct lack of knowledge amongst newly graduated engineers when it comes to SD. As a result, 8 out of 16 companies educate their own staff, or are presently developing an internal educational programme, in order to decrease the knowledge gap.

On a question to the alumni on what areas of education that they would have wanted more of while studying at Chalmers, the three areas that rank highest are economics, social impacts, and green technologies, see Figure 7. When comparing to Figure 6, it is clear that although environmental and resource issues are perceived to be among the most important, this is not the areas that are lacking the most. This also confirms the course content analysis which showed that the courses at Chalmers have a strong focus on environmental topics.

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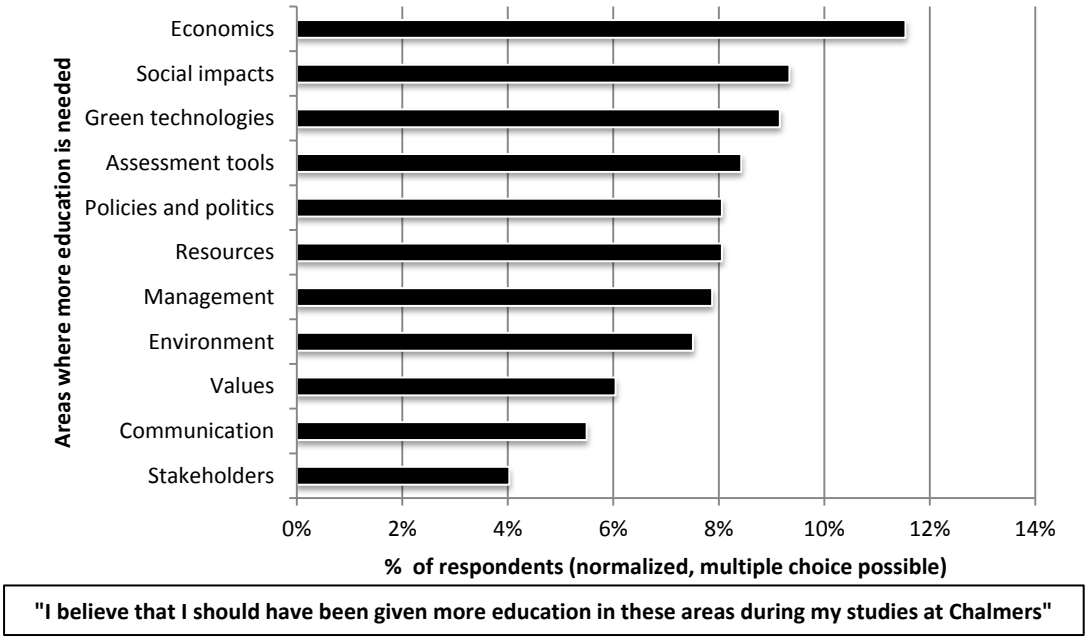

Figure 7: Gaps between competences achieved in education and needs of the professional role - results from alumni survey

The company interviewees mention communication problems regarding SD issues, and they also speak of difficulties amongst their employees in terms of their understanding of how their work is related to SD. This indicates a potential lack of integration of SD into courses. The company interviewees clearly stated that SD is something their employees meet in their daily work and in order to enhance the understanding of how SD may be interlaced in the daily work, education should mimic this integration of SD in daily work by integrating SD into other educational subjects. This was also mentioned by organisation interviewees.

According to the interview results, engineers should have a greater basic understanding for the natural resource constraints that our world is facing and the economic constraints and opportunities regarding SD. Insufficient areas, mentioned in the interviews in relation to SD competences, are economic and management issues relating to SD, which the company interviewees also see as important knowledge areas.

The analysis of course content in relation to the recommendations outlined in the guiding text on SD competences at Chalmers, shows that the guidelines are not implemented fully at any of the investigated programmes, since all programmes are missing one or more of the aspects outlined. Learning outcomes relating to communication across disciplines regarding SD issues, for example, is almost not addressed at all in the courses based on the course content analysis. This confirms the lack of communication related competences expressed by company representatives and also shows that the visions and internal guidelines for teaching and learning at a university may not correspond to the actual teaching and learning in the educational programmes. Additionally, competence areas relating to values, inter-generational justice, and ethical considerations seem to be insufficiently covered throughout the courses at Chalmers. Comparing the guiding text to the competences emphasized by the company interviewees and the alumni in the questionnaire also reveals that the guiding text lacks specifics regarding economics and sustainable business management, which are asked for by both alumni and company interviewees.

4 Discussion

4.1 Methodological issues

The method that is presented in this paper is believed to provide important input to the identification of the gap between needs of competences in industry and obtained competences in educational

programmes at universities. The results can thus provide valuable input for strategic decisions for education and quality improvements of courses in terms of ESD at universities, although it should be questioned how promptly and uncritically that universities should adapt to the perceived needs of companies.

The method can be adapted to fit the local conditions of a specific university. In our exploratory case study, the categories used for assessing course content, for example, were adapted to fit the course descriptions at Chalmers.

The authors created their own tool for categorizing and quantifying course content, inspired by commonly used educational and learning taxonomies. As a consequence, all course content analysis results are, to some extent, based on the authors' own understanding of SD and interpretation of the material. However, this is true for any analysis of this kind as it will always be limited by the analysts' understanding of concepts and tools and will be skewed towards their perspective. All the authors of this paper got their engineering education degree at Chalmers. Therefore, issues that might be clearly visible to someone from a contrasting system might have been lost or taken for granted without mentioning in this study. However, the authors have all been heavily involved in ESD curriculum development activities at Chalmers and understand many of the challenges and opportunities of the specific case.

The methods for studying competences obtained in engineering education are all indirect methods that provide only proxy data on the competences that are actually obtained. The questionnaires ask for the competences in SD, obtained by students and alumni, as perceived by the respondents themselves. This results in answers that are based on the respondents' opinions and knowledge, which means that a respondent with a deep understanding of the topic just as easily might answer that they have little insight, since they realise the enormity of the topic, while still having more competences than a respondent with little or no insight. Hence, there is a need for further investigation; actual learning outcomes need to be studied and related to course contents, and competence needs.

The majority of the company interviewees were part of the top SD management in the approached companies – results may therefore be skewed. Most of the company interviewees had a strategic rather than an operational role, hence very few actually performed the engineering work in question themselves. Due to this, very little detailed information on the specific competences needed could be collected. Thus, in order to increase the relevance of the research, a wider range of responsibilities in companies may be targeted. By conducting in-depth interviews with upper and lower management as well as with engineers in companies, working both directly and indirectly with SD, the validity of the research would increase since the risk of a biased population and skewed results decreases.

4.2 Are we educating engineers for sustainability?

This study indicates that Swedish industry needs a higher level and a broader range of competences related to SD amongst all engineers than university is currently providing. The areas of competences needed are not only environmental issues, which are most often focused on in the education at Chalmers, but additionally, sustainable business development, societal aspects and communication are seen as important areas.

By educating students through a comprehensive basic course in the subject of SD, the students appear to gain an understanding for the concept and its meaning. By further integrating SD issues throughout the programme, the students also seem to gain an appreciation for and understanding of SD as well as the interrelations between SD and professional work assignments.

The role of the university as an agent of societal change towards SD and more specifically the role of engineering education in this process needs to be further explored by technical universities. In this study, statements by industrial representatives and alumni have provided a major part of the input on what competences that are needed. However, university's role can go beyond educating engineers for the present needs of industry. The university should perhaps educate also for the future needs of industry and for the needs of the whole of society. This boils down to how universities perceive their role in societal change.

This article presents an exploratory case study using Chalmers as the study object, but also introduces a method that can be replicated elsewhere. However, it is recommended that further research should be conducted for individual educational programmes rather than for an entire range of

educational specializations at a university as presented in this paper. The reason is that there are large differences between different programmes and also between different sectors of industry, which demands a more thorough investigation related to each specific programme and its targeted sectors. In order to maximize the impact of a study like this, it is also advised that this research is carried out by or in close cooperation with a person responsible for the educational programme and in conjunction with other curriculum change activities.

Potential areas of future research are, for example:

- To create an assessment tool for evaluating the quality and level of actual competences in ESD amongst students
- To identify what areas of competences in SD that all engineering students should possess in order to meet the needs of the general industry for which they are educated, now and in the future, and to also look into the needs of specific sectors related to specific engineering specializations
- To explore how courses in SD can be designed for achieving the competences asked for, and identify indicators for the quality of the education in terms of ESD, and a process for ensuring the quality of the education

5 Conclusion

The three questions posed, *what competences do the students obtain in the educational programmes*, *what competences do the companies need*, and *what is the gap between what is obtained and what is needed*, revealed the presence of a gap between competences obtained and competences needed in the exploratory case study performed for Chalmers University of Technology in relation to some Swedish companies. The education at Chalmers has a strong focus on environmental issues, and less on economic and social issues. The alumni identify a need for more competences related to economic issues, sustainable business management, social issues and green technologies, than what they were provided in their education. The quantity of teaching on these topics and the level of integration into different courses in a programme seem to influence the results. Students that have been subjected to an extensive course in SD at Chalmers claim to have a good understanding of the topic of SD. Students who have been subjected to SD in several courses claim to have an understanding of the relevance for SD to their profession and to why they should study the topic. Other findings were that competences that relate to communication across disciplines regarding SD issues are normally not addressed in the courses, and competence areas dealing with values, inter-generational justice, and ethical considerations are also insufficient in comparison to the guidelines for ESD at Chalmers. Other insufficient areas, brought up by company interviewees, are economic and management issues related to SD, an area that company interviewees see as important knowledge for SD.

The companies ask for engineers with a higher general competence level relating to SD, and a thorough understanding of how SD affects their daily work.

This leads to the general conclusion that universities should provide ESD to all their engineering students in order to meet the needs of industry. According to the results from the Swedish case study, the course(s) should have an emphasis on environmental issues, but must have a reasonable emphasis also on economic issues, sustainable business management, social issues, and green technologies, in order to meet alumni and industry needs. The universities should also encourage the integration of SD into more courses, where relevant, in order to increase the relevance of the topic and make clear the connections to different knowledge areas to students, in order to introduce SD as an integral part of the work of an engineer.

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Preprint version. Final version appeared in International Journal of Sustainability in Higher Education, 2012, 13(3), pp 305-320: http://dx.doi.org/10.1108/14676371211242607

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