DEVELOPING CHANGE AGENCY FOR SUSTAINABLE DEVELOPMENT – EXPERIENCES FROM A NEW CHEMICAL ENGINEERING COURSE

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Abstract: The chemical engineering programme at Chalmers University of Technology in Göteborg, Sweden, has had compulsory courses on environmental science, environmental engineering and sustainable development (SD) at bachelor level for many years. This paper reports on curriculum development projects performed in 2013 and 2014 aimed at improving the quality of the program curriculum with regard to the compulsory content on 'environment and SD' and on experiences of planning a new course that was developed as a result of these projects: Perspectives on chemical engineering. The curriculum development projects contrasted the existing curriculum to syllabi from upper secondary school, to needs expressed by industry, alumni and engineering students, and to state-of-the-art engineering education for SD, and ended up in, among other things, ideas to be implemented in a new course in the first year. The new course focuses on introducing chemical engineering and the professional role of the chemical engineer, and developing change agency for SD. The new course was given for the first time in late spring 2015. In the course, the students are doing a smaller individual change project in which they change something in their daily life for a week and assess the impact and reflect on the challenges in making the change. They also do a larger group project in which they make a sustainability assessment of a considered sustainability-motivated change in chemical industry, including reflecting on the challenges in achieving change. Industry representatives help to guide the students in the project. The course also introduces basic concepts and tools like life cycle perspective, mass balances, biorefinery and industrial symbiosis. Special care is put into attempting to constructively align teaching and learning activities and assessment to the overall goal of developing students' change agency for SD. The paper reports on this endeavour. The presentation at the conference also reports on the actual experiences from giving the course for the first time, in particular in relation to change agency for SD.

1 INTRODUCTION

The important role of education for achieving sustainable development (SD) has been highlighted by e.g. the UN in the proclamation of the decade for education for SD (DESD), 2005-2014 (final report available on: http://www.unesco.org/new/en/unesco-world-conference-on-esd-2014/esd-after-2014/desd-final-report/), and the follow-up Global action programme (GAP) on education for SD (ESD), see http://www.unesco.org/new/en/unesco-world-conference-on-esd-2014/esd-after-2014/global-action-programme/. One of two objectives of the GAP is: "to reorient education and learning so that everyone has the opportunity to acquire the knowledge, skills, values and attitudes that empower them to contribute to SD – and make a difference". In line with this objective, this paper addresses the empowerment of engineering students to contribute to SD in order for them to "make a difference", focussing in specific on what is often referred to as 'change agency' or 'action competence'.

1.1 Change agency for sustainable development

The specific learning that is targeted in ESD has been described in many different ways. In fact, one of the major challenges in ESD is still the lack of detailed and universally accepted descriptions of the learning that should be targeted. Often, however, the core idea of ESD seems to be the same and therefore, dissimilarities in existing descriptions are likely primarily a result of a lack of efforts to find consensus on a common framework. Wiek et al. (2011) made a review of literature on sustainability in higher education and concluded that there is “convergence that sustainability education should enable students to analyze and solve sustainability problems, to anticipate and prepare for future sustainability challenges, as well as to create and seize opportunities for sustainability”, and also that “there is convergence in the educational literature about the critical role of defining key competencies and specific learning outcomes in order to successfully design and teach in academic programs”.

Svanström et al. (2008) made a review of texts on ESD competences and found that they commonly describe notions like systemic or holistic thinking and the integration of different perspectives, skills such as critical thinking, change agent abilities and communication, and that they all in some way address attitudes and values. Using literature review, expert workshops and surveys, Wiek et al. arrived at a description of ESD competences that focused on five areas: systems thinking competence (“to analyze a sustainability problem from a holistic perspective”), normative competence (to “assess a problem and its context comprehensively with respect to sustainability”), anticipatory competence (to “construct non-intervention scenarios about how the problem might play out in the future”; they also described a combination of anticipatory and normative competence as to “envision sustainable future states in contrast to the non-intervention scenarios”), strategic competence (to “create intervention strategies to avoid undesirable scenarios and realize sustainability visions”), and finally, interpersonal competence (to be able to work in “close collaboration with researchers from other disciplines, and stakeholders in government, businesses, and civil society”).

Already in the 1990s, similar ideas were described within the context of environmental education, under the term “action competence”. According to Jensen and Schnack (1997), "[o]ne of the overall objectives of environmental education is to build up students' abilities to act—their action competence—with reference to environmental concerns” and more specifically, they state that “the aim of environmental education is to make students capable of envisioning alternative ways of development and to be able to participate in acting according to these objectives”. The similarities between these statements and the much later texts on ESD are striking, although ESD can be claimed to have a broader scope than environmental education with environmental issues not necessarily being in the center of attention.

The notions of ‘change agency’ and ‘action competence’ are central in these descriptions and highlight the need for action, which is a central idea also in the objectives of the UN GAP that aims to “empower” people to “to contribute to SD – and make a difference”. Almers (2013), based on a review of literature, summarized important aspects of action competence as (1) commitment; (2) willingness and courage to act; (3) knowledge about consequences of and root causes to problems; (4) knowledge about and a capability to develop visions and possible solutions to a problem; (5) knowledge about how to influence and change conditions; and, (6) to be able to put this knowledge into practice.

So, what does this mean for current engineering education? Are we already promoting the development of change agency for SD to a sufficient level today? And if not, how can we teach for, and assess, this learning? This paper discusses these issues for the five-year chemical engineering programme at Chalmers University of Technology, Göteborg, Sweden, and ongoing efforts to address a perceived gap.

1.2 The chemical engineering programme and its context

The specific five-year chemical engineering programme has had compulsory courses on environmental science, environmental engineering and SD at bachelor level for several decades. In fact, since the 1980s, there has been a requirement that all five-year programmes at the university contain at least 7.5 higher education credits (hec) on “environment and SD” (E&SD) on bachelor level. This shows the strong commitment and the long-term effort of the university to contribute to SD. For a long time, this compulsory content on E&SD was not described in any detail but in recent years, recommendations for what type of

learning to address have been developed. In a document from 2009, developed in a consensus process involving interested teachers and programme directors at the university as part of a three-year reform project on ESD (described in http://www.chalmers.se/sv/om-chalmers/miljo-och-hallbar-utveckling/tidig-satsning-pa-miljo-och-hallbarhet/Documents/ESD_report.pdf), the following learning outcomes relate the strongest to change agency:

- Use problem solving, critical thinking and creative thinking, be able to communicate and cooperate, and be able to discern power issues in different decision-making processes in order to prepare for life-long learning and for becoming an effective change agent for SD
- Apply and shift between different perspectives in order to understand the situation of other stakeholders, and in order to be able to determine the viability of different options
- In a structured way reflect on his or her professional role and responsibilities as a professional and as a citizen in relation to SD

At master level, there is today a university-wide learning outcome for the master thesis, that the student should demonstrate:

- The capability to identify the issues that must be addressed within the framework of the specific thesis in order to take into consideration all relevant dimensions of SD.

In Sweden, there are also external requirements that push in the same direction. The University law states that all activities at universities must promote SD, and in the national degree ordinance for engineers, there is even specific mentioning of what this might mean, e.g., the student shall demonstrate:

- The ability to develop products, processes and systems, taking into account people's situations and needs and society's goals for economic, social and ecologically SD, and
- Insight into technology's possibilities and limitations, its role in society, and people's responsibility for how it is used, including social, economic, environmental and work environment aspects.

It is a pity that the notions of change agency or action competence are not so strong in the degree ordinance, however, in order to promote SD, as required by the university law, one can argue that universities may do this most efficiently by preparing their students to "make a difference" for SD.

In 2013, a review was made of all engineering programmes in Sweden by the Swedish Agency for Higher Education. It turned out very positively for the university as a whole with the highest relative number of programmes achieving the highest grade in the whole country, and the five-year chemical engineering programme being one of these successful programmes. With regard to the two bullets in the degree ordinance given above, the first one was deemed to have very high goal fulfillment and the second one only high goal fulfillment. In fact, for the first goal, it was specifically mentioned that: "Courses like "Chemical engineering, environment and society", "Chemical environmental science" and "Products and processes in a sustainable society" are good indicators that the student has the possibility to reach a high goal fulfillment" – these courses are all part of the compulsory course load on E&SD in the programme. For the second goal, it was stated that "compulsory activities that can ensure that the students get a holistic view of SD that includes how economic aspects are interconnected with and in some cases counteract SD are missing" (the full report, in Swedish, is available at: http://www2.uk-ambetet.se/download/kvalitet/bio-kemi-miljo-energiteknik-2012.pdf).

Even with this relatively high goal fulfillment in the evaluation, one cannot claim that the programme's role in preparing the students to actually act towards SD was fully evaluated, although the assessed competences may make up an essential part of that ability. Further, the students in the chemical engineering programme, along with many other students at the university, have been complaining for many years that the compulsory courses are not appropriately considering their preknowledge and their specific specialization, making the courses seem not so relevant to the students and thereby achieving a low grade in student and alumni evaluations. In fact, this issue was addressed, university-wide, by a specific quantitative goal in the annual five-year plan for 2012-2016 with regard to the employability of students: "The average score on the alumni survey concerning how satisfied alumni are with their

education as a whole is at least 8 (out of 10), and the average score on the question about their knowledge in the area of E&SD is at least 6.5 (out of 10)".

In an internal review of the engineering programme curricula within the field of chemistry, physics and mathematics at the university, performed in 2011-2012, concern was raised, among other things, over the quality of the courses on E&SD in the chemical engineering programme. At the same time, programme leaders were writing self-evaluation reports for their programmes within the review of the Swedish Agency for Higher Education, and this issue was therefore a hot topic also for them. It was decided that a working group would start reviewing the compulsory E&SD courses to suggest how the perceived issues could be addressed. The curriculum review and reform projects that were performed, described below, resulted in, among other things, an outline of a new course.

1.3 The scope of the paper

This paper reports on the curriculum development projects performed in 2013 and 2014 aimed at improving the quality of the programme curriculum with regard to the compulsory content of E&SD, which resulted in an outline of a new course: Perspectives on chemical engineering. The paper also reports on the preparations for the course, and the presentation at the conference reports on the actual experiences from giving the course for the first time, in particular in relation to change agency for SD.

2 THE CURRICULUM AND COURSE DEVELOPMENT PROJECTS

Two different curriculum development projects were performed that provided input to development of the new course. The curriculum development projects contrasted the existing curriculum to syllabi from upper secondary school, to needs expressed by industry, alumni and engineering students, and to state-of-the-art engineering education for SD, and ended up in, among other things, an outline of a new course in the first year. When the curriculum development projects were carried out, it had already been decided that there would be some changes in the programme curricula in terms of e.g. the size of some courses; see Table 1 for details.

Table 1: E&SD courses in the chemical engineering programme curriculum when the reform project started, and suggested new curriculum.

	Old curriculum	New curriculum
Year	Course, Total size (E&SD content)*	Course, Total size (E&SD content)*
First	Chemistry, 18 (1.5)**	Chemistry, 18 (1.5)**
First	Chemical engineering, environment and society 4.5 (4.5)	New course, 6 (6)
Second	Energy technology and environment 4.5 (1.5)**	Energy technology, 3 (0)**,***
Third	Chemical environmental science, 4.5 (4.5)**	Chemical environmental science, 4.5 (4.5)**
Third	Processes and products from a sustainability perspective, 7.5 (3)	Processes and products from a sustainability perspective, 7.5 (3)

*Given as higher education credits (hec) according to the ECTS system; 1.5 hec corresponds to 1 week of full-time studies

**This course is also part of the chemical engineering with physics programme

**This course was later moved to the third year to enable a strong connection to the Chemical environmental science course

As Table 1 shows, the major difference in the suggested new curriculum is thus the new course in the first year and the apparent disconnection between energy technology and some E&SD content, at least in terms of that it is moved from that course context.

2.1 The two curriculum development projects

A working group was appointed in November 2012 to review the courses on E&SD at bachelor level in the two five-year programmes chemical engineering and chemical engineering with physics. The stated reason was the lack of quality perceived by students, in that context described as “normative content, overlaps and lack of progression”. The group consisted of four teachers and five students in the programmes and the methods used included a review of descriptions of programme curricula and course syllabi and of earlier evaluations of programmes and courses, and discussions within the group, with industry representatives and with course examiners and programme directors. The report was delivered to the programme directors in May 2013 and it contained, among other things, the following recommendations:

- Ensure that courses build on the students’ preknowledge from earlier levels of education
- Introduce an industrially relevant project in the Chemistry course in the first year
- Continue the project in the new course for the chemical engineering students in the first year
- Revise the new course for the chemical engineering students in the first year thoroughly in comparison to the old course and focus on the professional identity
- It is suggested that the department employs a ‘professor of the practice’ to strengthen the compulsory courses on E&SD

Already in June 2013, a new working group was appointed, consisting of four teachers in the programmes, with the task to suggest purpose and learning outcomes for the E&SD content in the following courses: Chemistry, the new course and Chemical Environmental Science. The group reviewed syllabi from upper secondary school to ensure that the first-year courses would continue from that level and it reviewed recommendations and requirements from local and national degree ordinances. It also looked at all ESD related learning outcomes from compulsory E&SD courses at the university.

A first description of purposes and learning outcomes was sent out to a larger group for feedback and a final version was reported to the programme directors in December 2013. The results cannot be reported in detail here; the learning outcomes for the new course are discussed in section 3. The suggestions differed from current practices primarily in the following ways that are relevant for this paper:

- Some basic tools and concepts such as safety data sheets, life cycle perspective, industrial symbiosis, bio-refineries and risk assessment were more strongly emphasized
- Change management was made explicit in learning outcomes
- Handling ethical dilemmas was made explicit as a learning outcome

2.2 Course development projects

The author of this paper, who had participated in both described curriculum development projects and has been teaching in this field since the 1990s, was appointed to be the examiner of the new course and was given some money to perform a special course development project in 2014 to outline the details of the course according to the suggestions from the curriculum reform project. In discussion with the programme director, the course was given a name and an additional learning outcome that focused on presentation techniques to address also one of the so-called generic and transferrable skills addressed in the programme. More details on the new course are provided in section 3. Special care was put into aligning teaching and learning activities and assessment to the overall goal of developing students’ change agency for SD; constructive alignment, see e.g. Biggs and Tang 2011, has been the recommended tool for curriculum design at the university for many years. A matrix showing how learning outcomes mapped to teaching and learning activities and assessment in the course was discussed with teachers that would participate in the new course and also with teachers that would teach in relevant courses that would come before and after the new course in the curriculum to provide feedback for further refinement and to allow for planning of progression in learning within this field in the whole curriculum.

Another project was started in the fall of 2014 and aimed at developing the industrially relevant projects that had been suggested by the first curriculum development project. The new student projects would be performed by groups of students, first in the Chemistry course and then in the new course. This project was performed primarily by the examiners in the courses and a newly appointed 'professor of the practice', whose appointment was also recommended by the first curriculum development project. The purpose of this relatively new type of appointment at the university is described in the university's appointment regulations in the following way: "One way of expanding the university's competence in the latter stages of the undergraduate education is to engage people with advanced engineering skills and longstanding professional experience of engineering projects. They may have acquired specialist competence in either the public or private sector". The person that was part-time employed for this purpose was a chemical engineer with a very long experience from different levels in chemical industry. He also had a lot of networking experience, e.g. as a leader for the West-Swedish chemistry cluster, encompassing organizations from university, institutes, industry and public authorities.

The student projects were developed in collaboration with industry and carried out within the Chemistry course from November 2014 to February 2015. In all, about 60 students were involved in 12 projects focusing on six different tasks in five different large companies in forest, petrochemical and chemical industry. The project in the chemistry course focussed in particular on chemistry and the properties of molecules in everyday products. The new course is given back-to-back with the Chemistry course, and the students continue their projects on new aspects in the new course.

3 THE NEW COURSE: PERSPECTIVES ON CHEMICAL ENGINEERING

The new course focuses on introducing chemical engineering and the professional role of the chemical engineer, and on developing change agency for SD. The name, Perspectives on chemical engineering, suggests that the course will explore multiple perspectives of chemical engineering. The purpose of the course is described as: "The course introduces chemical engineering and offers different perspectives on chemical engineering in a broader sense, with SD as a starting point. A particular focus is put on identifying needs for change and consequences of and obstacles to achieving such change".

The learning outcomes are expressed in the following way: "after completion of this course, the student should be able to:

1. describe chemical and chemical engineering industry and its specific preconditions and challenges, including social, economic and environmental aspects
2. use mass balances to estimate the size of mass flows
3. describe what is meant by life cycle perspective, biorefineries and industrial symbiosis, including the ideas behind these concepts and the challenges that come with them, including social, economic and environmental aspects
4. describe the challenges involved in changing chemical and chemical engineering industry, including social, economic and environmental aspects
5. describe the challenges involved in changing their own or other people's behaviour
6. perform a simple environmental impact assessment for a change in chemical or chemical engineering industry
7. discuss relevant presentation technology for different contexts".

Teaching and learning activities include lectures, exercises, individual assignments, an individual project and a group project. Assessment of the different learning outcomes is made by means of written texts (individual assignments and project reports), oral presentations (of project results), participation in some activities, and a written examination in the end of the course. In the following, two of the teaching and learning activities that relate strongly to change agency, and thus the part of the purpose described as "identifying needs for change and consequences of and obstacles to achieving such change", and learning outcomes 1, 4 and 5, are described.

The project that involves the same groups as in the chemistry course, and continues the work in the same industrial setting, but with a different focus, makes up almost half of the course. The focus is on chemical engineering and its industrial and societal context. The students perform a sustainability assessment of a considered sustainability motivated change in industry, e.g. a change from a petrochemical feedstock to a bio-based one in a certain process. This assessment includes making an environmental impact assessment, something that is required by law in Sweden when important changes are considered in industry. The students are asked also to focus on the change process itself and reflect on if the considered change is likely to happen and why or why not. They are assessed by means of a written report and an oral presentation. The idea is for the students to get insight into the sustainability challenges of industry, of efforts to overcome the challenges, and of what efforts are successful and not and why.

In the course, the students are also doing a smaller individual change project in which they identify a change in their daily life that might have a positive impact on sustainability. They then make this change for a week, assess the impact quantitatively in a relevant way, and reflect on the challenges in making the change. They hand in an individual report that describes what they have done before they are all gathered for a seminar. At the seminar, they first briefly present and discuss their findings in small groups, and the most important findings are then presented by each group to the whole class. The idea is for the students to get insight into many different ideas and actual attempts to decrease the sustainability impact of consumption and understand what typical opportunities and challenges there are in achieving this change, and also understand what might bring about large and important positive impacts and what might be less important to change in everyday life.

The new course is given for the first time in late spring 2015 and when this paper was written, the course had thus not yet been given. However, the presentation at the conference includes a discussion on the experiences from the first course.

4 DISCUSSION

This paper is an attempt to explore the idea of change agency for SD in chemical engineering education. The first question one may ask is whether it is a relevant goal that students develop this change agency during their studies. Given the strong focus on change agency in ESD literature in general, as was discussed in the introduction, it seems to be relevant as a goal. Given the important role that engineers and technical companies have in shaping the technical systems, products and services in society and the strong connection to both environmental impacts and human well-being, it seems particularly important that engineers are well-equipped in this sense. Further, it seems unlikely that it would be enough to start developing this competence after the university studies have ended.

Change agency is still an elusive concept. What it means in practice and how we should teach for and assess this competence is not yet well described in literature. This forces the individual teacher to start exploring the concept on his or her own, discussing ideas with peers, trying out ideas and reflecting on and documenting effects, much like the effort described in this paper. Each such effort may take us one step further towards understanding the full implications of this concept and hopefully, over time, this will lay the foundation for more rigorous research studies. Since the concept it still so elusive, the next question that needs to be asked is more difficult to answer, in fact, even the question is difficult to formulate: does the new course contribute to developing change agency for SD for the students, and if so, how and why? One way to address this question at this stage, before the course has even been given, is to reflect on whether the aspects of action competence outlined by Almers (2013) are addressed. The aspects ‘commitment’, and ‘willingness and courage to act’ are not explicitly addressed and definitely not assessed within the course. However, one may argue that their experience of performing the projects may make them more prone to doing similar things in the future. In particular, the individual project involves both envisioning and carrying out change. The idea is to follow up after the course ends if students actually adopt some of the practices they have tested and if they even adopt practices that they were told about by other students. The aspect ‘knowledge about consequences of and root causes to problems’ is definitely part of the course and this will also be assessed. Further,

'knowledge about and a capability to develop visions and possible solutions to a problem' is something that could potentially be more explicitly taught in the course and it would be possible to assess to some extent even in the written examination with an essay type question. Finally, 'knowledge about how to influence and change conditions' and 'be able to put this knowledge into practice' is something that they will work with in the project and that can be touched upon in the assessment.

5 CONCLUDING REMARKS

It is clear that the students do get the chance to develop some important aspects of change agency in the course but that there are things that can be improved. They will get experiences from a change process but will they get appropriate experience of taking action? Further, how well they develop these aspects may be difficult to assess.

The described course is given in the first year and alone makes up only a small fraction of the full chemical engineering programme. Development of change agency is something that must also be addressed on a programme curriculum level and an analysis of the whole programme and discussions with many other teachers is therefore warranted. What could progression in learning towards change agency in chemical engineering education look like? How can different courses address different aspects? These things need to be further explored.

The effort described in this paper is only a first step towards understanding how to better develop change agency among students in chemical engineering. It has raised new questions on what makes up this competence and how it can be taught for and assessed and how it can be dealt with on a programme level. On-going research efforts on e.g. problem-solving (e.g. Lönngren 2014) and systems thinking (e.g. Lönngren and Svanström 2015 and Nyström Claesson and Svanström 2015) for SD will likely provide useful elements to the understanding of this complex competence.

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