To improve the ability to reflect on your own research in relation to sustainable development - experiences from a course for PhD students at Chalmers University of Technology

Magdalena Svanström, Anna Nyström Claesson, Jonas Nässén, Maria Knutson Wedel, and Ulrika Lundqvist

Chalmers University of Technology

Abstract

One of the most important student learning outcomes of education for sustainable development (ESD) is for the student to understand, or be able to find out, the most important sustainability considerations in relation to his or her own specific situation. In the spring of 2009, a short course for PhD students on the Challenges and Opportunities of Technology in Sustainable Development was offered for the first time at Chalmers University of Technology. The course is offered to all PhD students, as a semi-compulsory part of an ethics course requirement. The course centres around a writing assignment in which the student is asked to reflect on his or her own research in relation to SD. As support and input, the students participate in nine different lectures with seminar discussions, all giving different perspectives on technology and SD, interview three different persons, participate in a peer-review student seminar, and have an individual discussion with a faculty member. Assessment is performed by hand-in of the essay, compulsory presence at 80% of the lectures, and reviewing of texts of other students.

This paper explains the idea behind the course and shares experiences from giving the course twice in 2009. Learning was evaluated using concept maps, before and after the course. Furthermore, the final essay texts were analysed and results compared to results from concept maps. The course seems to have resulted in an overall improvement in the students' attitudes towards sustainable development (SD); particularly they show less focus on environmental aspects. However, the course has a greater impact on students with already existing SD awareness, here attributed to the opportunity to build on already existing knowledge. The development among students novel to SD was not necessarily captured in the concept maps but in some cases apparent in the final essay, which might be considered as evidence of transformative learning.

Introduction

In suggested frameworks for education for sustainable development (ESD), complex analysis and reflection are desired skills. As an example, the following is stated for Swedish higher education (translated from Swedish): “To be awarded the Civilingenjör degree (MSc in Engineering) the student should be able to demonstrate:

- the ability to formulate judgements considering relevant scientific, societal and ethical aspects, and demonstrate an awareness of ethical aspects on research and development work,
- insight into the possibilities and limitations of technology, its role in society and the responsibility of humans for its use, including social, economic as well as environmental and occupational health aspects”

It is often emphasized that individuals need to have an ability to understand the most important sustainability considerations in relation to their specific situation, and thereby be able to take considered action - be able to make choices in a responsible way, both as professionals and as citizens. This has been a guiding principle in the work on ESD at Chalmers University of Technology (Chalmers) for many years. This principle leads to a number of assumptions that underpin ESD activities at the university:

1. *Sustainability considerations should not be the responsibility of only a few selected individuals* or experts, but rather something that we should all address in our daily life. We should all feel this responsibility and be provided support in building the required competences. In order to make sure that relevant sustainability consideration are addressed, we must find ways to make sure that sustainability is always on the agenda. Sustainability involves life-long learning and building of competences and is not something you can learn in a crash course. However, the building of the desired competences can be started in an appropriately designed course, and by other activities that make people reflect on the consequences of their different choices in relation to sustainable development (SD).
2. *The challenges involved in SD will shift as the world changes.* Our understanding of the interconnectedness of the world and on how this complexity and the uncertainties involved in planning for the future should be handled is also under development; suitable frameworks and methods are not yet in place. Which sustainability considerations that are the most urgent or important to address will vary between specific situations and will change as the world develops. Therefore, sustainability always has to be addressed based on the specific situation surrounding the issue in question in terms of the state and the trends of natural and societal systems, considering relevant aspects both in the local and in the global context.
3. *A broader understanding of potential sustainability implications of the own area of responsibility is therefore needed, as well as an ability to reflect on the implications from different perspectives*, e.g. different generational, cultural, temporal and geographical perspectives [e.g. 1]. This type of learning is sometimes referred to as transformative, as it may have a profound impact on how we look upon the world and on the choices we make.

These principles and assumptions are a driver for and an important ingredient in ESD work at Chalmers. Chalmers has for many years had a strong commitment to contributing to SD, both in research, in education and in outreach. ESD has been more or less compulsory in the educational programs since the mid 1980s, when a 7,5 hec (higher education credits) course, corresponding to five weeks of full-time studies, on environmental issues was recommended to be included in all undergraduate programs. This later became compulsory and shifted in focus towards the broader SD area. In order to further stress to students the importance of SD in university activities, introductory lectures on SD for new students, on undergraduate, on master, as well as on doctoral programme level, have now been standard procedure for several years.

In 2008, a working group was given the task to develop a course for PhD students by the vice president responsible for PhD level education at Chalmers. Even though the aim was clear, there is not much literature on different course designs for graduate students that actually result in transformation in thinking and in an increased capability of reflection, and there is also a lack of methods for assessing this type of learning. In SD, behavioural change is important and education is perceived as one of the strongest means to accomplish this change, either through classroom teaching leading to transformative learning or through the result of a student's internal mental processes. In both cases, the knowledge must be perceived as meaningful.

This paper describes the ideas behind the course for PhD students, what underlying assumptions that are behind the design of the course syllabus and the use of a combination of essay text analysis and concept maps to assess student learning in relation to the desired outcomes. It shares both ideas on how sustainability considerations can be addressed in a graduate level course and on how the students' learning process can be followed and assessed.

Course idea and syllabus

The perceived problem that led to the formation of this course is that PhD students do not have a strong enough ability to reflect on their own research in relation to SD. Since they do not have this, they will not be able to act as effective drivers towards embedding of sustainability considerations in research at the university. The university will then not be able to live up to its strong vision: Chalmers - for a sustainable future. The idea was therefore to strengthen this ability by helping students to think about sustainability and the potential relation to their own research from different perspectives, thereby training them in understanding the potential implications of their choice of research topics and methods and the way in which research results are disseminated.

The working group that was given the task to suggest an outline for the course based their work on the principles and assumptions described above. These are based on earlier experiences of ESD at the university. Ideas behind the suggested outline were:

- In order to increase the ability to reflect on your own research in relation to SD, you must be given the opportunity to develop and exercise this ability
- In order to be able to reflect on SD, you need to be able to construct your own mental models of SD in relation to the specific issue
- In order to be able to understand what other perspectives there may be in addition to your own, you need to get input from other sources
- When your perspective is confronted with other perspectives, you become more aware of what assumptions that underlie your own research assumptions. This may lead to that you question your own perspective and assumptions and that transformative learning takes place
- You understand the basic assumptions and implications of an idea through explaining, arguing and discussing with others, both orally and in writing

The course was given the name Challenges and Opportunities of Technology in Sustainable Development. It was offered as one out of three elective ethics courses of 3 hec (corresponding to 2 weeks of full-time studies). All PhD students at Chalmers need to finish one of those courses before they can get a licentiate degree (about 2-2.5 years into, or halfway through, their PhD studies). The outline is shown in Figure 1.

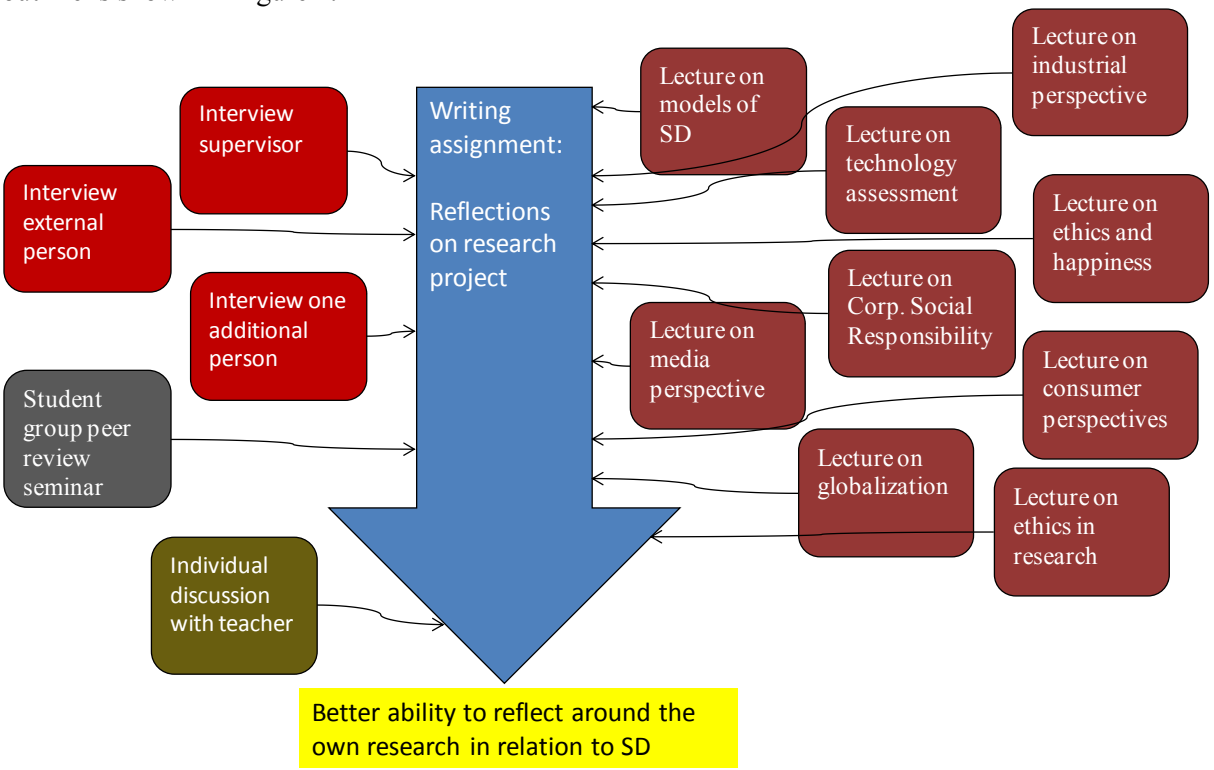

Figure 1. Outline of the PhD course Challenges and Opportunities of Technology in Sustainable Development.

The course centres around a writing assignment in which the PhD student is asked to reflect on how the own PhD research project relates to SD. Issues that are discussed as potential areas to describe in the project are e.g.:

- Anticipated benefits for different stakeholders
- Anticipated risks and costs for different stakeholders
- Important ethical considerations in relation to methods or results
- Implications on how the results should be disseminated
- External preconditions that need to be fulfilled in order for results to be useful

- Possibilities to steer methods and topics towards SD
- Additional information needed to tell whether the project can contribute to SD or not

The goals and the student learning outcomes of the course are described in the course information as follows:

The course aims at:

- training the students' ability to reflect on their research topics in relation to SD, taking all relevant aspects into account
- giving insight into the opportunities and challenges of technology, both in general terms and in relation to the own research project

After completion of the course, the students should be able to:

- Describe the importance of understanding the consequences for SD of different technological choices
- Describe their role as individuals and researchers in the context of SD
- Define and describe important ethical, environmental, social, cultural and economical considerations related to their research

The class meets during five full days, one week in between each. Dividing them into half-days, nine of these are dedicated to getting input from different lecturers and one half-day is for a student peer review seminar. In addition to this, the student has to make interviews and prepare, and improve, an essay. The learning modules are organised as follows:

- Nine different lectures, with group and class discussions, that handle different perspectives or areas of SD feed into the essay work. The lecturers are from different disciplines in academia or from surrounding society. Most lecturers also recommend literature to the students. Typically, each lecture is about 1.5 hour and after the lecture, the lecturer asks the students to discuss in groups around certain issues that connect to the theme, and eventually the class meets again to discuss their findings with the lecturer.
- The students are asked to interview three different persons in order to get further input to the writing assignment. One person has to be their supervisor, in order to get input from someone who normally has longer experience within the field, but also in order to stimulate discussions on SD within the research groups. Another person must be someone who is not a researcher and has not a close relation to the project, in order to get input from an external perspective. The third interviewee can be selected freely by the PhD student.
- Half-way into the course, students are divided into groups of about five students, and students are asked to send the preliminary texts of the essays to the other group members. Students read all texts and fill in a review protocol. These review protocols are handed over in connection to a peer-review seminar during the fourth week of the course, in which students provide feedback to other students on the content, structure and the language of the texts. Within the groups, each student leads a discussion around his or her own text for about 20 minutes and then receives the review protocols from all other students.

Examination requires attendance at lectures and seminars (80%) and the writing of the essay. About one week after the last day of classes, students have to send in an improved essay to an assigned faculty member and make an appointment for a feedback discussion. This discussion serves to give individual feedback to the student from someone who has been reflecting for many years on how their research contributes to or relates to SD. Typically, these teachers have a long experience of working with SD related issues and ESD (the authors of this text are some of these teachers). The teacher guides the discussion based on the learning objectives of the course. After this feedback, the students are asked to update their text once more, and to send in a final version. The texts are not graded; what matters is that students have made efforts to improve their texts at least twice, after the student peer-review seminar and after the discussion with the assigned faculty member.

The course has now been run three times, in May 2009 (first course), November 2009 (second course) and May 2010 (third course) with only minor modifications to the described set-up. The next section discusses efforts to assess whether the course had been successful in reaching the goals or not.

Course evaluation and assessment of learning

Different efforts have been made directed at understanding whether the learning outcomes were achieved and if the overall principles and ideas seem to have contributed to this. The PhD students' learning processes where both stimulated and assessed by drawing concept maps and by writing an individual essay text. The course was also evaluated using a more traditional student questionnaire.

Course evaluation - student questionnaires

After each course, students have been asked to fill in questionnaires on their impression of the course and whether the course lived up to the expectations. The students were asked to provide grades on a set of questions on a scale from 1 (bad/to a low degree) to 4 (very good/to a high degree) as well as to provide written comments and suggestions. To date, only the first two courses have yet been evaluated. The response rate was rather low for these evaluations (5/32 for the first course and 4/14 for the second course) and hence the results should be interpreted with caution. Here, we give some results based on a combination of the two evaluations, i.e. responses from 9 PhD students.

The average overall mark on the course was relatively high (2.9 on the scale 1-4). The students also appear to find that the course was helpful in reaching the three intended learning outcomes (see earlier in the text), by grading the perceived learning 2.8, 3.0 and 2.9 for the three learning outcomes. The students were also asked to what degree different parts of the project work helped them to reflect on their own research projects with different SD perspectives. The peer-review seminar in which the students provide feedback to each other's preliminary essays was rated as very helpful (3.3) as was the individual meeting with the supervisor (3.3). The interviews carried out by the students were rated as less helpful (2.3).

While the students seem to be rather positive towards most of the course elements, most of them do not expect to use the acquired knowledge from the course in their further PhD studies to any larger degree (rating 1.6). This is perhaps not so unexpected since many students already have a working plan for their studies and some are in their final part of their PhD project. It might also be a sign of lack of transformative learning. In that case this might be attributed to the short extent in time of the course. The all in all about two months that the course lasts might be too short to allow for new ways of thinking to fully develop.

Assessment of learning - concept maps

The use of concept maps in teaching is a metacognitive method based on Ausuble's theory on meaningful learning and involves making a graphical representation of the hierarchy, the mental structures and the organisation of the knowledge [2]. Knowledge is described in many ways but is often thought of as the ability to use a discourse (i.e. system of concepts) in an adequate way [3]. A concept is a word that is connected to a phenomenon. The more complex the phenomenon, the more concepts can be assigned to describe it [4]. According to Ausubel's assimilation theory, knowledge is created and learning starts when [2,4]:

- knowledge develops and become meaningful, i.e. worth learning, and new concepts can easily be connected to already known concepts
- the cognitive structures of the knowledge are hierarchical
- more structure and details are added to the cognitive structures (progressive differentiation; knowledge deepens).

Meaningful learning takes place when knowledge is well structured. In a concept map, concepts are interconnected in hierarchical structures that are linked to a central concept in a graphical representation. A concept can be described as an action, an occasion or a phenomenon that can be labelled [5]. Concepts can be interconnected into principals that describe the relation between the concepts' function or structure. The structure in a concept map, i.e. the links between concepts and the level of detail, describes how well the student has managed to organise their knowledge [7,8].

A concept map can thus reveal if knowledge is well organised or not. A sun-shaped map lacking links between concepts with a low number of hierarchies and few details, is normally the result of a memorising learning strategy. Concept maps that are the result of meaningful learning have a high number of hierarchies, relevant links between concepts, lots of details, and a clear structure [4,9,10]. A

third type of map is the messy map characterised by being decentralised, with a lot of concepts and links between concepts that are not necessarily relevant. These maps are difficult to assess and interpret. One possibility is that the knowledge is complex, another that the knowledge is new and not fully assimilated and a third that the concept map is the result of a messy mind [10].

The literature reports on different areas of use of concept maps: to organise curricula, to structure information from interviews, a metacognitive tool (a way to make thinking visual), or as a tool for assessment. Novak used cognitive maps to transcribe interviews relating to knowledge development in pupils in natural sciences in a longitudinal study of 12 years [4,5]. Turns *et al*. used concept maps for evaluation at course and program level [10]. Teacher students have used concepts maps to access their supervisor's tacit knowledge about teaching [11]. Another study evaluated student's knowledge about global warming [2] and concept maps have also been used as part of an examination to assess the structure of knowledge [7].

In engineering education, concept maps have been used to evaluate the perception and the learning of students in courses on sustainable development [10,12-14] and to evaluate students' or educators' learning after a course in sustainable development [15,16]. In a recent dissertation from University of Barcelona [16], concept maps were used to evaluate engineering students' development of SD skills such as systemic thinking and critical thinking. The study includes case studies of 5 universities from different parts of Europe, both in and outside the European Union. The results showed that the students' knowledge varied depending on pre knowledge, the teachers' philosophy of teaching and the students' societal context. One of the student groups were master students in the beginning of their master studies in a sustainability course and their understanding of SD was much deeper than Bachelor students', probably due to their higher level of pre knowledge. Students' understanding of SD as well as the transdisciplinary perspective of SD and systemic thinking were all better developed in student groups that had been involved in student centred learning activities where the teacher used a multi methodological approach to teaching. In most of the case studies, the engineering students' concept maps focused on environmental and technological aspects of SD except in the Ukraine case study where the students included a higher degree of the societal concepts in their maps. This was explained with the rather recent transition from communism to market economy in Ukraine that emphasises the social aspects in the students' societal context.

Shallcross used concept maps to evaluate how engineering students' knowledge was distributed in relation to the knowledge that can be expected from an engineer in a future sustainable society [14]. The results from 732 concept maps showed that the dominating areas were environmental, technological, and societal impacts and values, which agrees well with the study performed by Segalàs Coral [16]. Less pronounced in the study were other societal institutions and understanding of the intra- and intergenerational perspectives of SD.

Concept maps can thus serve as images of students' understanding of SD before and after a course. The first two times the PhD course was given, students were asked to make concept maps of how they think about SD. This was done as the very first thing in the course and at the end, before the final teacher feedback on the essay. Students received 15 minutes to draw a concept map on what they relate to sustainability, after being shown a concept map for a completely different area. Students were asked to write down both the concepts and the connections between the concepts, including words that describe how the concepts are connected.

Evaluation of the concept maps was quantitative using 8 categories proposed by Lozano-Garcia *et al*. [15], which are an expanded version of the categories suggested by Lourdel *et al*. [12,13]. The original categories suggested were:

- Social and cultural aspects
- Environmental aspects
- Economic, scientific and technical aspects
- SD principles connected to durability, issues relating to Agenda 21, solidarity and future generations, complexity, temporal and spatial dimensions
- Procedural rationality and political aspects
- The participative dimension, actors and stakeholders

Lozano-Garcia et al. [15] divided the category "economical, technical and scientific aspects" into "economical" and "scientific and technical aspects" and added the category "education". The

categorisation of the concepts was determined by the context of their position in the students' concept map.

Our evaluation shows that the average number of concepts in the concept maps is 13.8 before the course and 16 after, the highest number achieved was 32 concepts before and 29 after the course. The distribution of concepts between the different categories is presented in Figure 2. In order to provide comparison to another group, the average number of concepts from this study is compared to the results from Lozano-Garcia *et al*. [15], who evaluated learning in a group of educators at the University of Monterrey

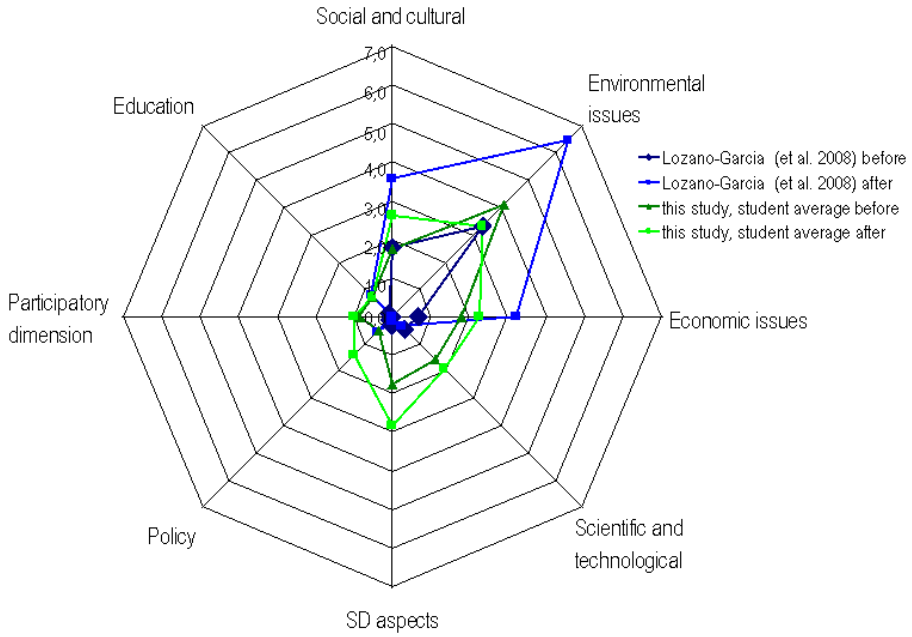

Figure 2. Comparison of the average of different categories in concept maps evaluated in this study, before and after the course, with a similar evaluation done by Lozano-Garcia *et al.* [15].

It can be seen that the participants in the Mexican study show an emphasis on the environmental area as well as in the social and economical areas, and that this emphasis increase during the course. In the present study, students have a higher reference to other concepts related to SD and to their domain of profession and after the course, they broaden their view to include more social, cultural and SD aspects.

The increase in the number of concepts in our study, as indicated by an increase in the average number of concepts, was not significant for the whole student group. The students all fall in either of two groups, one small group showing a high level of awareness already from start and a larger group seemingly having less SD experience and that does not change as much after the course. Figure 3 shows a comparison between the four maps with the highest number of concepts (16-32 concepts before the course and 26-30 after) with 23 students having a much lower number of concepts. The most significant shift in the small group with many concepts is from a dominant environmental focus towards other areas, such as SD aspects, economic aspects, and social and cultural. The result from the large group with less concepts shows that there has been an improvement but much less pronounced.

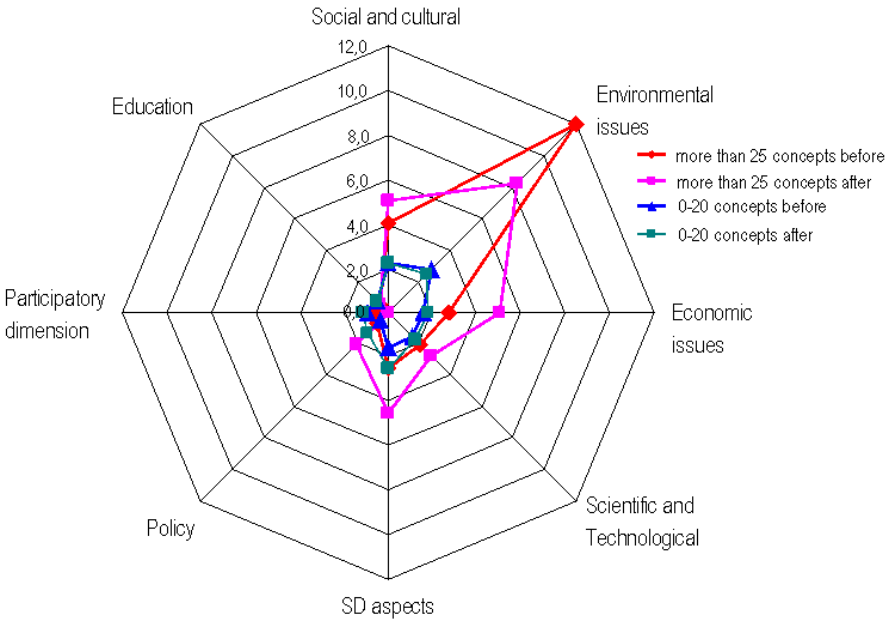

Figure 3. Comparison of concept maps from four students with a high number of concepts (generally more than 25) with the rest, 23 students, having less than 20 concepts both before and after the course.

Assessment of learning - essay text analysis

In order to provide input on how the students' thinking about SD had developed and matured during the course, the final versions of the essays were analysed and used as to complement the results from the concept maps in evaluating the students' learning process. The final essays were evaluated according to three criteria based upon the three learning outcomes of the course:

1. The learning outcome: "Describe the importance of understanding the consequences for SD of different technological choices" was translated into a first criterion that related to the student's ability to problematize the choice of **technology** within their research project and handle different aspects of SD. Two different categories were identified:
   - Business as usual: Traditional evaluation based upon the degree of efficiency and area of applicability of the technology, marked as "*efficiency/application*" in Table 1
   - SD norms: Evaluation based upon the function of the technology and environmental impact from it, marked as "*function/environmental impact*"
2. The learning outcome "Describe their role as individuals and researchers in the context of SD" was described in a second criterion, characterising how active they perceive their **role**. The students' perspective on their research was put in relation to how they plan to participate in communication of their research. Two categories were identified:
   - *Active*: Characterised by a focus on society or stakeholders, with an aim to influence decision-making and that they perceive themselves to be an active part by using multiple channels to communicate results
   - *Passive*: Characterised by a focus on the research community where their aim is to produce knowledge and they perceive themselves as unbiased researchers
3. The learning outcome "Define and describe important ethical, environmental, social, cultural and economical considerations related to their research" was used to formulate a third criterion that aimed at indicating the number of **perspectives** the students had mentioned and reflected upon e.g.:
   - Ethics (e.g. responsibility, fairness in relation to living and future generations and value of nature)
   - Environmental impacts (e.g. environmental load, resource depletion)
   - Social aspects (e.g. ethnic, religion, gender, policy)
   - Economic aspects (e.g company, marketing, long term strategies for meeting environmental and sustainability challenges)

The results from the text analysis are shown for each of the included 27 students in Table 1 together with the total number of concepts from the concept maps.

Table 1. The results of evaluating the essay texts and the number of concepts in the maps for each student

	Technology	Role	SD aspects	Concepts before	Concepts after
1	Efficiency/application	Passive	Many	14	6
2	Efficiency/application	Passive	Few	0	11
3	Efficiency/application	Passive	Many	19	15
4	Efficiency/application	Passive	Few	12	13
5	Efficiency/application	Passive	Few	15	9
6	Efficiency/application	Passive	Few	17	17
7	Function/env. impact	Active	Many	23	26
8	Efficiency/application	Passive	Few	19	22
9	Function/env. impact	Active	Many	32	29
10	Function/env. impact	Active	Many	19	17
11	Efficiency/application	Active	Few	5	20
12	Function/env. impact	Active	Many	17	18
13	Efficiency/application	Passive	Few	5	17
14	Efficiency/application	Passive	Few	10	14
15	Function/env. impact	Active	Many	22	5
16	Efficiency/application	Passive	Few	5	10
17	Efficiency/application	Passive	Few	9	13
18	Function/env. impact	Active	Many	13	16
19	Efficiency/application	Passive	few	11	18
20	Efficiency/application	Passive	Few	6	15
21	Function/env. impact	Passive	Many	5	3
22	Function/env. impact	Active	Many	30	27
23	Function/env. impact	Active	Few	16	16
24	Function/env. impact	Passive	Many	8	15
25	Function/env. impact	Passive	Many	10	17
26	Function/env. impact	Active	Many	14	13
27	Function/env. impact	Active	Many	16	30

Students 9 and 22, for example, have a close correlation between a high number of concepts in their concept map and their capability to reflect around their research projects in relation to SD. The suggested explanation is that these students entered the course with relatively well developed knowledge in SD and that the new knowledge presented in the course was easily assimilated and perceived as meaningful.

In some cases, e.g. for student 26, the concept maps contained relatively few concepts but the essay showed that the students were able to discuss SD in relation to their research and saw possiblities to use their results in a wider audience than the research community. The total number of concepts in the map is average but the essay may still indicate fulfilment of the course learning outcomes on problematising around the research technology, expressing a number of different aspects of SD and showing an active researcher's role. This suggests that the learning process was influenced by input between the final concept map and final hand-in of the essay. Close at hand is to assume that the student already had started a learning process that was not finished when the final concept map was produced. It can also be assumed that the teacher response occasion helped the students to structure and organise their thinking, i.e. knowledge, in such a way that it became meaningful. Another explanation is that the student did not make a serious effort in producing the concept map, knowing that it would not be important for passing the course.

Assessment of learning - teachers' reflections on feedback discussion

Furthermore, teachers that met the students for the final feedback discussions on the essay were asked to reflect on their experiences of how students conceptualize SD and discuss around their research in relation to this. One such reflection is that since most students work in projects that aim at improving certain aspects of industrial processes, products etc (e.g. wood pulping and logistics), which is normal at a technical university, students often state that these improvements lead to a decrease in costs and emissions and thereby promote SD. However, it is more rare that students question whether the process or product is the right thing to do in the first place. Also, most students do not think about the indirect consequences of the increase in consumption volume that the research might lead to. This somewhat simplistic view on ecological sustainability, in which the idea is that sustainability is reached through increases in eco-efficiency, the students unfortunately share with many other important actors in society. To push the students beyond this into broader reflections on indirect consequences and into an increased sense of responsibility has become a major task for the teachers in the feedback discussions.

Discussion on assessment of learning and goal fulfilment

The results from this study suggest that students that came to the course with a profound knowledge on SD and multi-faceted perspectives in relation to SD found the course extra meaningful. For these students, the issues brought up during the course could probably easily be connected to already established mental structures, thereby deepening their knowledge. The majority of students that attended the course were, however, not as well prepared, and this group was the actual target group. The concept maps show that a large group of students have a rather unorganised way of structuring their knowledge around SD and the new issues brought up during the course had no natural place to connect to in their mental structures. This could be explained by that this group of students lacked pre knowledge in SD and to be able to follow the course, they used a memorising learning style which left no time for deeper reflection during the course. In some cases, the response on the essay helped the students to organise their mental structures in such a way that their understanding increased and became meaningful, and the students eventually perceived themselves as change agents. However, there is a chance that learning processes have been started in a good way and that time itself will be enough for the students to become more mature in their thinking about sustainability. A longitudinal study could reveal this.

One question that needs to be asked is whether the methods used to assess learning and goal fulfilment in this study are relevant and effective. Concept maps were used, but these are difficult to interpret and might not reveal the learning outcomes that were targeted in the course. Text analyses have similar problems. Discussions with students, however, will relatively easily reveal the approach that students take in relation to the intended learning outcomes, and students also get a chance to explain further what they might have missed in maps and texts. All three methods are time consuming. However, all three methods can be part of teaching and learning activities as well. The use of concept maps as a tool for analysing and structuring knowledge can be taught and trained in a course, writing assignments are fantastic tools for improving the clarity of thinking around different topics, and feedback discussions can meet students on an individual basis, pushing them forward in the needed areas.

If the results from this study are representative of the actual learning that takes place in the course, one has to ask oneself why the majority of the students didn't learn more during the course and what could be changed in order to improve the learning. Since students have the possibility to choose between three different ethics courses, one might assume that the students that pick this course are interested to learn more on how their research relates to SD and are motivated to actively participate in the course. However, it is known that several students select this course due to much more practical considerations, mainly related to when the course is given. Efforts to increase their motivation before the course starts could prove effective. Furthermore, pre reading of certain material that can give a good background to SD and can start to form a mental model for the student around their research and SD is another possibility. The essay could also be used as a tool throughout the whole course with a first short text being asked for already before the course starts, as an introduction to other students and

to leturers. A requirement of an up-date of the essay half-a-year after the course could also prove useful.

A spin-off effect of the course is that a dialogue in the students' research groups is potentially started since students are asked to discuss SD considerations with their supervisor. This is very much in line with Chalmers' way of dealing with embedding and mainstreaming of ESD and SD at the university.

Conclusions

Complex competences that are often asked for in ESD are difficult to assess. Concept maps, text analysis and discussions with students, methods that were used in this study, are all time consuming and not very precise in assessing learning, but they are all useful also as tools in learning.

The course seems to result in an overall improvement in the students' attitudes towards SD; particularly they show less focus on environmental issues. However, there is a greater impact on students with already existing SD awareness, here attributed to the opportunity to build on already existing knowledge. The development among students novel to SD was not necessarily captured in the concept maps but in some cases apparent in the final essay, which might be considered as evidence of transformative learning.

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