Developing sustainability learning outcomes for engineering

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Abstract

The Swedish higher education ordinance specifies a number of learning outcomes for different types of educational programs. For the five year engineering programs (bachelor plus master), two of the learning outcomes are clearly connected to sustainable development. These are

For a Master of Science in Engineering the student shall
- demonstrate the ability to develop and design products, processes and systems while taking into account the circumstances and needs of individuals and the targets for economically, socially and ecologically sustainable development set by the community
- demonstrate insight into the possibilities and limitations of technology, its role in society and the responsibility of the individual for how it is used, including both social and economic aspects and also environmental and occupational health and safety considerations

These outcomes are sometimes seen as rather general and difficult to use in practical work. There could thus be a need for further definitions and specifications. In a process, the two general outcomes were further defined into ten more specified learning outcomes. It was suggested that these could be used for development of programs and courses and also for evaluations. Some of the ten specified learning outcomes are generic for all programs and some need to be further specified for the different programs. The specified learning outcomes were discussed within the faculty and the faculty council of KTH decided that they could be seen as recommendations and they welcomed further development and discussions. During spring 2012 all educational programs were asked about their opinions on the specified learning outcomes. The respondents were in general rather positive and suggested that they could be used for program and course development. They also suggested different types of improvements. In this paper, the suggested specified learning outcomes are presented. Reactions from the survey and different types of meetings are discussed. Suggested improvements are presented.

1   Introduction

Many universities struggle with change processes, including implementation of education for sustainable development (Holmberg et al, 2012). KTH Royal Institute of Technology started the project KTH-Sustainability 2011 with the aim of developing KTH's education, research and cooperation with society with respect to sustainable development. The project will be evaluated in 2015 and a decision on its continuation or reorganisation will be taken after that. KTH-Sustainability works closely with the Environmental manager at KTH who is developing the Environmental Management System.

KTH has a double strategy regarding implementation of education for sustainable development:

- To have educational programmes focusing on sustainable development
- To integrate sustainability in all engineering and architectural programs.

The first part of the strategy is currently working quite well. KTH started a new 5-year Masters of engineering program in Energy and Environment which is attracting a healthy amount of qualified students. In addition there are several 2-year Masters programmes focusing on sustainability issues. KTH-Sustainability is therefore focusing on the second part of the strategy, to integrate sustainability in all programmes. The need for this was also stressed by the Education Assessment Exercise performed at KTH in 2011 where it was noted that several of the education programmes need to develop the integration of sustainable development. Also surveys with KTH alumni but also at other universities (e.g. Hanning et al, 2012) indicate this need. Several development projects were also initiated after the EAE, including development of new courses.

In Sweden, overall learning outcomes for MSc and BSc in engineering and architecture programmes are set by the Government in the Degree Ordinance, an appendix to the Higher Education Ordinance. Some of these concern Environment and Sustainable Development (ESD).

For the MSc in engineering, students are required (outcomes 7 and 11) to:

- *"demonstrate the ability to develop and design products, processes and systems while taking into account the circumstances and needs of individuals and the targets for economically, socially and ecologically sustainable development set by the community"*
- *"demonstrate insight into the possibilities and limitations of technology, its role in society and the responsibility of the individual for how it is used, including both social and economic aspects and also environmental and occupational health and safety considerations."*

The requirements for the BSc in engineering are almost identical. The major difference is that in the first point, "*develop and design,*" is changed to "*design and manage.*"

The requirements for the MSc in architecture are also similar:

- *"demonstrate the ability to plan, design, maintain and renew built environments and buildings in complex contexts and with a holistic approach informed by various demands, in particular the sustainable development required by the community"*
- *"demonstrate the ability to adopt a holistic view in making judgements and appraisals informed by the relevant disciplinary, social, aesthetic and ethical aspects and which at the same time take into account the different needs and functional abilities of communities and individuals as well as the interaction between individuals and their physical settings, including occupational health and safety."*

The present strategy chosen at KTH is not to prescribe a specific course on Sustainable Development, or that a specific number of credits should be taken. Instead, the overall learning outcomes described above are taken as the starting point, and it is clearly communicated that it is the schools responsible for the programmes and the programme leaders who are responsible for the achievement of these overall learning outcomes. The best ways to achieve the learning outcomes may be programme specific and should not be decided at the KTH level. From the KTH level, KTH-Sustainability is instead monitoring and providing different types of support.

During 2012 we asked all programme leaders to do a self-evaluation describing the extent they are fulfilling the overall learning outcomes. This is now (spring 2013) followed up by discussions with all schools where they are asked to write an action plan for developing their programmes regarding the

integration of sustainable development. During 2015 we will do an evaluation of all Engineering and Architectural programmes with regard to their integration of sustainable development. This is also related to one of the overarching environmental goals. So the review will also be a part of the environmental management system and reviews related to the certification processes.

When discussing with programme leaders and teachers it became apparent that the overall learning outcomes can be difficult to use. They are, almost by definition, general and widely perceived as being difficult to work with. As a result, they may need to be made more concrete and specific. Some aspects can then be general for all programmes, while others will have to be programme-specific. Making them more concrete can be useful when drawing up programme- and course-specific learning outcomes. They can also be useful when assessing programmes to see which courses address the different learning outcomes. The development and use of more concrete learning outcomes can also contribute to a discussion and consensus on what students should learn about sustainable development at different levels within KTH. KTH-Sustainability therefore initiated a work to develop specifications of the overall learning outcomes. The aim of this paper is to present the current version of these specified learning outcomes and also to present some reactions to these from KTH faculty.

2   Method

The specified learning outcomes were developed in an iterative process from October 2011. Successive drafts were discussed in several meetings including two workshops with teachers at KTH, several meetings with the steering group of KTH-Sustainability consisting of faculty and students from KTH and two meetings with the Faculty Council which in March 2012 decided that these specified learning outcomes should be seen as advisory. They also stated that they would like to see guiding learning outcomes being developed.

As a part of the self-evaluation of all engineering programmes described above, programme leaders (coordinators) were in the survey asked about their opinions on the specified learning outcomes.

3   Specified learning outcomes

Below is the proposal for more concrete learning outcomes. The proposed outcomes are still general, and therefore relevant for all MSc in engineering programmes (other programmes are discussed below). The outcomes are seen as more concrete versions of the overall outcomes, so they do not in fact go any further than them. Programme-specific outcomes may also be required. Footnotes are introduced to explain some terms and give examples.

Students should be able to

1. give an account of and assess how the student's knowledge and skills can influence and contribute to sustainable development.[1]
2. give an account of and discuss the concept of sustainable development with respect to motive, history, definition[2] and the most important global challenges. Students should also be able to

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[1] This point presumes much of the knowledge mentioned in the outcomes below, but is put first to highlight that it is of central importance

[2] Sustainable development is traditionally defined as development that ... *meets the needs of the present without compromising the ability of future generations to meet their own needs.* Sustainable development is often described as consisting of three dimensions: ecological, social and economic sustainability. In Sweden, ecological sustainability is often defined through the Swedish environmental

      provide examples of connections between ecological, economic and social sustainability.

3. give an account of Swedish, EU and UN objectives within sustainable development[3]. Students should also be able to discuss scientific perspectives on politically set objectives.[4]

4. describe which activities and technologies have the greatest impact on global and Swedish sustainability[5]. Students should also be able to describe possible strategies to consolidate such positive impacts and counteract negative ones.

5. describe how those parts of society that the programme of study addresses affect global and Swedish sustainability[6]. Students should also be able to describe and assess possible strategies to consolidate such positive impacts and counteract negative ones.

6. give an account of economic and institutional factors that can explain a lack of sustainable development.[7]

7. describe, assess and apply different generic strategies that are used in connection with development and design of products, processes and systems that contribute to sustainable development.[8]

8. describe, assess and apply different sector- and technology-specific methods and strategies used in development and design of products, processes and systems that are relevant for the programme and that contribute to sustainable development.

9. identify and understand the link between environmental aspects and business opportunities, specifically for the individual sector.

10. discuss ethical aspects, the gender perspective and other legal aspects of sustainable development.[9]

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quality objectives. The three dimensions overlap and depend on each other. The concept of ecosystem services can also be introduced under this point, to explain why working ecosystem services are a precondition for sustainable development. (Ecosystem services are those that society obtains from a functioning ecosystem. Examples include climate regulation, water purification, production of foodstuffs and materials, and recreation). Examples of other concepts that can be introduced are "carrying capacity" and "ecological modernisation." It can also be of interest to analyse different stakeholders' approaches to the concept of sustainable development.

[3] For example, the Swedish environmental quality objectives and the UN's Millennium Goals. These are targets set at a high level and not reviewed particularly often.

[4] One example might be that Sweden's, the EU's and the UN's objectives for climate change are encompassed by what is called the "two-degree target" (that the maximum increase in global temperatures should be 2°C), while many researchers claim this is a high-risk objective that could lead to serious effects. Another area concerns the concept of risk, the precautionary principle, which types of risks society is willing to take, and on which grounds decisions can be made.

[5] For example, it is important to understand that transportation, housing and food supply contribute most to many of our environmental problems.

[6] One example is that students at the ICT-programme should be able to address how the ICT sector can affect sustainability

[7] For example, it can be relevant to address the term "external costs". (One example of external costs can be economic losses due to problems sleeping on account of traffic noise. These costs are not borne by those who generate the traffic, but by other parties.) Another example of institutional factors is "the tragedy of the commons." A further example of institutional factors is legislation.

[8] Examples include the use of end-of-pipe technologies, ecodesign and sustainable consumption. The strategies should include a systems perspective with a life-cycle approach.

[9] Aspects that can be addressed include the fact that some challenges and objectives primarily concern women, that women and men impact on environmental and sustainability aspects differently, and that women and men are affected by environmental and sustainability aspects differently

Of these 10 learning outcomes, numbers 2-4 and 6, 7 and 10 are generic, while points 1, 5, 8 and 9 must be addressed in specific programmes. The programme-specific outcomes in particular might need to be developed in individual programmes. The generic learning outcomes can be taught and examined in a specific course or integrated into existing course in the programme. In both cases it is important that teachers have sufficient expertise and that it is examined separately. (Separate examinations are required so that students cannot deselect sustainable development parts of a course and still qualify). Outcomes 1, 5, 8 and 9 should be integrated into the programmes. Also here it is essential that there is sufficient expertise and that it is examined separately. When integrating the learning outcomes, also progression may have to be considered.

The specific learning outcomes above are primarily aimed at the MSc in engineering programmes. The overall learning outcomes for BSc in engineering and MSc in architecture are similar to those for MSc in engineering, which means that after some modifications, the proposals should also be applicable there.

4   Reactions on the proposal

During the development of the proposal there were quite a lot of discussions and we received a number of reactions, both detailed and on a general level. Some of the comments were integrated in the proposal. On a general level five broad groups of partly contradictory reactions and comments were given:

1. Specified learning outcomes should not be developed.
2. Specified learning outcomes are useful and should be developed.
3. The specified learning outcomes are too ambitious.
4. The specified learning outcomes are not ambitious enough.
5. There is too much emphasis on environmental aspects of sustainability and not enough on social and economic aspects.

The response from the programme leaders on the specified learning outcomes provided in the survey was in general positive. Several programme leaders pointed out that the proposed learning outcomes are already implemented in the educational programmes and courses, but that the clarification of the outcomes is welcome. The concrete learning outcomes provide a useful tool during formulation of the programme-specific and/or course learning outcomes. For a few programmes the corresponding outcomes were in-line with the ambition of the educational programme and the future development of more specific programme learning outcomes. A few programme leaders, however, think that the overall learning outcomes set by the Government in the Degree Ordinance are sufficient enough and that the clarification would provide an unnecessary middle level and an extensive amount of outcomes. One of the respondents pointed out that the examination of the proposed outcomes should be at the end of the studies, so that the students have sufficient knowledge attained throughout the duration of the programme.

The programme leaders are doubtful to implementation of the proposed outcomes as guiding and prefer to keep them as advisory, so that each educational programme can develop their own outcomes connected to the specific subject and regulate the level of knowledge. The outcome number 3 was questioned by several programme leaders with the motivation that the outcome is too specific and not relevant on the programme-level.

There is a request to adjust these specified outcomes to another enactment level with respect to relevance, clarity, facilitation to examine and effectiveness in assessment of the students' knowledge.

Specifically, the taxonomy of the outcomes should focus on deep learning, reflections, analysis and critical thinking. The proposed outcome would then be more concrete for implementation in both the educational programme level and the course level.

5   Discussion

The discussion on what engineers should learn on sustainable development remains a challenge that needs to be discussed (Mulder et al, 2012). It is important to discuss competencies (Wiek et al, 2011) but also learning outcomes including taxonomy (Segalàs et al, 2009, Svanström et al, 2008). In order to achieve a constructive alignment between learning outcomes, activities and assessment, the formulation of the learning outcomes is an important part (c.f. Biggs, 2003).

The aim of the development of the specified learning outcomes was to get a tool that would be useful in the implementation of sustainable development in engineering programmes. In general the programme leaders had a positive reaction and many leaders and teachers found the list useful when developing programmes or courses. Perhaps to our surprise, the strongest criticism in some cases came from teachers working with sustainability issues and people working with pedagogic issues. The latter group were in some cases critical because they thought that there should not be any specified learning outcomes on KTH level. Instead it should be developed bottom-up and being programme specific. They often emphasised the importance of the process, perhaps paying less attention to the content. The sustainability teachers were in some cases critical because they thought this became an oversimplification of a much more complex area. In contrast, some engineering teachers found the list of specified learning objectives useful, because they got a simple to use tool that they could use, for example as a check-list.

In some of the footnotes, there is a focus on ecological sustainability rather than the economic and social aspects. This is partly because there are more operational definitions of ecological sustainability (for example, in Sweden there are the environmental quality objectives for ecological sustainability, but no equivalent for economic and social sustainability). This also reflects a general perception of the difficulties of integrating social sustainability in the engineering programmes (Edvardsson Björnberg and Skogh, 2013).

In line with the Faculty Council's decision, the suggested learning outcomes shall be regarded as advisory. There is however an intention to produce guiding outcomes, which means there is also reason to continue the discussion and to gain endorsement for these outcomes. In these discussions, the criticism must also be taken into account. The more learning outcomes are used in conjunction with programme and course development and appraisals, the more experience we will gain. There have also been requests for collections of examples and proposals for activities and examinations that can be linked to these learning outcomes. A pilot version of a tool-box with best-practise examples is therefore being developed. A course for teachers on teaching for sustainable development will also be developed. In these and other ways KTH-Sustainability will continue working on these issues. It is clear that embedding of sustainable development in engineering education is a long-term process (Svanström et al, 2012). During this process different tools need to be developed and experiences from other universities should be used.

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