Engineers of the future: using scenarios methods in sustainable development education

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Abstract

Scenario methods are used and taught in a variety of courses related to sustainable development by teachers at KTH – the Royal Institute of Technology in Stockholm, Sweden. In this article we explore how futures studies approaches, understood in a wide sense, can contribute to education for sustainable development. Based on our experiences from these courses, we identify positive outcomes as well as some key challenges. The four courses presented and discussed in the paper include 3rd through 5th year courses from engineering programmes in urban planning, media technology, and industrial design.

1 Introduction

Sustainable development is fundamentally about the future; in the sense of exploring what a sustainable future might look like, and in the sense of understanding how present actions, be it decision making, product development or urban planning, relate to that future. However, the future, according to a Western secular thought tradition is not something that exists but something that becomes. This means that the future exists only as a product of our personal and social imagination, and thus that it is outside the scope of objective observation (Karlsen *et al*., 2010). Agreeing that the future does not exist in any predetermined sense is a prerequisite to seeing it as possible to influence, i.e. we are not governed by fate, but it also means that there always will be larger or smaller elements of surprise. We can anticipate and influence the future but we cannot predict or control it (Bell & Olick, 1989). The future oriented character of sustainable development thus implies a need to manage uncertainty, in both the shorter and longer term, and also to deal with conflicts that arise between these two time perspectives (Adam, 2004).

Moreover, sustainable development is also characterized by complexity and ambiguity. Ever since the Bruntland report (WCED, 1987) was published, sustainable development has been seen as achievable only through a successful integration of subsystems of different types and levels (Berkres & Folke, 1993; Sverdrup & Svensson, 2004; Weaver & Rotmans, 2006; Kemp *et al*., 1998). Adding to both complexity and uncertainty is the fact that these systems and their interrelations are not static but dynamic (Svenfelt, 2010).

Together this renders traditional engineering education problematic as it often builds on prediction-based approaches to solve well-delimited and well-defined problems (Fenner *et al*., 2005). In order to be able to understand, critically reflect upon and put sustainable development into practice, engineering students need to learn how to identify and manage uncertainty, the tension between short and long term perspectives, complexity, and the inherently normative

character of sustainability. Moreover, in order to tackle complexity, inter-disciplinary and integrative skills are needed.

This paper looks at the ways that futures studies approaches can provide a fruitful set of tools to these ends. The field of futures studies is here understood in a wide sense, encompassing all sorts of approaches aimed at developing scenarios, visions or design fictions. However, while the literature on futures studies as a research method, and a planning tool is extensive, there is less written on its usefulness in teaching and learning for sustainability; the sole exception found being Quist *et al*. (2006). In this paper ideas on what knowledge, attitudes and skills (KAS) that engineering students need to develop to contribute to sustainable development are compared to commonly perceived strengths of futures studies. The contributions of futures studies to ESD are then exemplified through a number of courses, including courses on futures studies as well as courses using futures studies methods or approaches.

2 Education for Sustainable Development

The literature on Education for Sustainable Development (ESD) is extensive. Given the scope of this field of study this is no surprise. Besides reflections on learning processes and learning experiences, ESD also includes accounts on the structure and context of the educational institutions. Moreover, ESD also include a number of different disciplines and topics, sometimes treated separately, and sometimes combined in inter-disciplinary and systemic approaches. However, there are a number of common and re-occurring traits and themes concerning what capacities and skills students (or all people) need to learn to contribute to a better world. Breiting (2007:19) speaks of an "'action competence' linking the ability to cope with identified present problems with possible wanted futures and adequate actions." Drawing on e.g. Breiting (2007), Fenner *et al*. (2005), Tilbury (2010) this action competence includes:

- To deal with complexity, 'fuzzy', and ill-defined problems,
- To work with different time spans, linking the present with the (un)desired future,
- To work holistically, with a systems perspective, and base this on contextual characteristics,
- To understand sustainable development as an ambiguous concept, including conflicts as well as synergies, and to address ethics and values related to this,
- To understand that sustainable development cannot be achieved by technology or traditional engineering skills and knowledge alone, and thus, to work inter-disciplinary, participatory and in teams,
- To make use of creativity, innovation and imagination to open up the 'design space' of possible solutions,
- To evaluate options, based not only on technological or economical feasibility but also ethics and values, contextual characteristics, and the openness of both the design space and the future
- To use this, not only for a better understanding of sustainable development challenges, but for carrying out real change projects.

3 Futures Studies

Futures studies is a multi-disciplinary field of study aimed at exploring, inventing, proposing and assessing different futures (Bell, 2003). In education, futures studies can be the topic in

question, i.e. a philosophy and set of methods to learn to apply, or used as a creative and/or critical approach within other disciplines. In this paper we understand futures studies as encompassing scenario techniques such as scenario planning (van der Heiden, 2006), and backcasting (Quist & Vergragt, 2006), as well as design, engineering and literature based approaches such as speculative design (Lukens & DiSalvo, 2012), design fictions (Sterling, 2009; Wakkary *et al*., 2012) and science fiction (Dourish & Bell, 2008). We do however demarcate the field through pointing at a number of properties that we think are crucial for futures studies to do 'their job' in addressing, analyzing and promoting sustainable development.

A first property is the elaboration of one or more representations of a future state, i.e. in terms of scenarios, visions, images of the future and design fictions. This is also one of the characteristics that differentiate futures studies from other future oriented approaches such as weather forecasts, strategic impact assessment, transport modeling or policy analysis.

A second characteristic of futures studies is the way uncertainty is handled. Futures studies do not address epistemic uncertainty, meaning uncertainty that can be resolved through more knowledge. That kind of uncertainty is better dealt with through other disciplines. Instead, futures studies address the ontological uncertainty resulting from the "fact" that the future is open, that some issues are too complex and dynamic to ever be fully mapped out, and that they also can be ambiguous in the sense of having multiple and equally valid interpretations. However, futures studies do not leave uncertainty and ambiguity hanging in the air but deal with it through organising and bounding it through creating multiple, contrasting scenarios. In this way uncertainty can be specified across, rather than within, scenarios (Schoemaker, 1993). Through using futures studies in ESD the students can thus required to address uncertainty explicitly, and in this way contributes to learning-through-practicing how to take on complex and 'fuzzy' problems.

Third, and related to this, futures studies (often) have an explicit aim of increasing the perceived scope of possible solutions, i.e. the design-space, through pointing at the inherently uncertain character of the future and the resulting wide range of possible futures. Through formulating the aim of assignments as exploring and widening the design-space rather than find the 'best' solution within a predefined space, futures studies encourages and demands the students to make use of their imagination, creativity and innovative capacity (Fenner *et al.*, 2005).

Fourth, futures studies are issue-driven (Robinson, 2008). It is the problem or challenge at hand that determines what disciplines need to be involved, instead of having the discipline determine what problems to address. This means that futures studies are beneficial for problem-based learning (PBL). In education however, this ad hoc approach to interdisciplinary work usually needs to be bounded so as to make the task fit to the students' competences as well as the length of the course or course moment.

Fifth, futures studies demand contextualization and integration. A scenario should be the result of an "informed imagination". This means that both fact and fiction are needed in order to create a scenario that is realistic and relevant but that goes beyond the present or historical. A scenario should also be comprehensive and consistent, which implies that it does not suffice to develop only a new concept, product, service or lifestyle but that this needs to be integrated into its context, i.e. a bigger picture of societal change and/or stability. This means that futures studies at the same time promote a holistic and integrative approach to problem solving.

Sixth, while the process of developing scenarios is a fruitful way of exploring and testing dependencies and inter-dependencies in a holistic way, the resulting images of the future can

also be used as a basis for further analysis and discussion, for example highlighting goal conflicts, conflicts between different time perspectives, and the normative and transformative characteristics of sustainable development (Höjer *et al.*, 2012).

Comparing these six characteristics of futures studies with the 'wish-list' of KAS for sustainable development it seems as futures studies approaches have good potential to positively contribute in a number of educational situations in terms of facilitating a contextually situated, problem based and practical way of learning, and opening up for discussions on difficult questions that otherwise risk not being addressed.

4 Four examples of courses

In this section we present and reflect on four examples of courses in which futures studies has been used.

4.1 Futures Studies and Forecasts

At KTH, first year masters students in planning have been offered a course in Futures Studies and Forecasts for about 15 years. Today the course is part of a Master Programme in Sustainable Urban Planning and Design. Over the years the course has become increasingly focused on rather open futures studies, whereas the degree of more formalised modelling and forecasting is now only a small part of the course. The course consists of lectures, workshops, group work, a literature assignment and a final seminar. In the workshops the students get the opportunity to try some workshop methodology for generating scenarios, which is followed up by a group assignment related to scenario development. The final seminar is held in smaller groups. During the final seminar, the students present and discuss their own and another student's "literature assignment". This assignment is the major part of the examination. Here, the students write a 6000 word memo where they compare a city's comprehensive plan with the course literature, and try to find out relations between planning and futures studies.

The course focuses very much on the students' ability to take active responsibility for their own learning. The students get to try out a number of different approaches and take part in seminars and workshops that do not always explicitly fit together. Moreover, almost all work is done in groups. They are informed about this during the introductory lecture in which they are informed that they are to find the red thread of the course themselves – and show that they have managed in the final literature assignment. After the final seminar the students write a 1-2-page individual text explaining how they would have improved their paper, if they had been given the chance. This assignment is included in the grading and have been shown to be an efficient way to grade the students' final understanding of the course, including the insights they get during the final seminar in which their literature assignments are assessed through peer and teacher review.

This course is not explicitly focusing on sustainable development, as the examples below. However, the course is given at an environmental department and has understanding of long-term thinking in relation to environmental threats as one of its aims. Thus, the students get aware of the importance of long-term thinking for the environment, and of the importance of taking environmental threats into account in long-term thinking. One of the main benefits of this course is that it empowers students to analyse and make claims on how the future is and should be treated, which indeed is a crucial task for future planners with an interest in sustainable

development. For others the course provides training in how to bring in difficult environmental problems into long-term planning with other first objectives.

The rationale for having a course in futures studies in a planning program is that the planners to be learn that the future is not an existing entity, which they just need to uncover. Instead the course emphasizes that the future is open and that it can and will be affected by both the processes and outcomes of planning. This in turn means that society can be changed. The intended learning outcomes of the course include an understanding of this, as well as knowing what tools and approaches that exist in futures studies and in what situations they are suitable.

In the course most students pass through some stages during the course, with the first being total confusion as to what futures studies is, and the last being at the discussions in small groups during the final seminar, where most students are confident and content with what they have learnt.

4.2 Sustainable Planning & Design

"In 2010, concerned Annedal residents felt the need to reduce the dependency on private cars in order to have a more liveable and sustainable neighbourhood. They started the "What if?*" association, to get the residents to think "outside the box".*

[---]...a proposal for having shuttle minibuses was sent to Stockholm and Sundbyberg municipalities. These municipalities had difficulty in convincing SL[1] because it was not profitable for SL to serve this small group of residents. Combining school minibuses with these suggested shuttle buses was a solution proposed by the municipalities' planners. As a result, it was accepted that these municipalities would provide part of the funding for this demand response project in cooperation with SL. Today, these shuttle minibuses provide 2 types of services during the day. In the morning and early afternoon, they pick up children at home and leave them to school and the opposite for the way back, which makes it easier to leave children to go alone to school. For the rest of the day, they provide cross-district and direct (door-to-door) services for as many residents as possible, especially disabled and old people." (Granath et al., 2011).

Students wrote the scenario from which this is excerpt in a project course within the Master Programme Sustainable Urban Planning and Design. All students attending this course have also taken the course in Futures studies and Forecasts. This programme aims at going beyond current practice of addressing the challenge of urban sustainable development, and does so through including elements of scenario building and futures studies, actor collaboration and governance, and sustainability assessments. The scenario project directly addresses the first and third point, and indirectly the second, as elaborated in the following. During the seven years that course has been given, groups of students have produced more than 30 scenarios, and the discussion that follows is based on experiences from these.

The excerpt shows that the scenarios consist of narrative text, told from a future 15-20 years from now; this is often written as a journal article. Furthermore the scenarios have descriptive and analytic text, like an ordinary planning document, and also diagrams, tables etc. Just as in ordinary planning, these scenarios use real place and people as a point of departure – in this case a Stockholm City District. To retain complexity the students learn this through a case study approach (Flyvbjerg, 2006; Stake, 1995). Scenarios are generated starting with a counterfactual

[1] SL is the public transport organisation of Stockholm, Sweden.

"What if…" question, for example: "*What if ICT were innovatively used in Södermalm's buildings and transport systems to automatically control energy use as well as to inform and persuade users to use less energy?".* To move from today's reality to a 2030s scenario, students collect prognosis-based data on for example demographics of the district or on the development of ICT technology, which once again can be done through the case study approach. However, the aim is to go beyond or counter prognosis, exploring the freedom of action of planners, local actors and citizens. The students do this through creative brainstorming, and a "Mental Time Travel" method was sometimes also used. This merges the whole to a scenario of the district, as transformed according to "What if…". After scenario generation proper, the students assess the contributions to urban sustainable development, using a comprehensive check list, BREEAM Communities, or qualitative cost-benefit analysis.

A key element of the brainstorming is "What-Who" iteration: All transforming measures of the scenario should take place in the city district and have a local actor as agent of change. Furthermore the scenario should have a balance between actors and measures. To this end the students are asked to include so called "What-Who" tables in their scenario reports. This is an indirect way of highlighting the actor or governance perspective as stated in the programme aims.

Experience shows that the students, although they come from different Bachelors' Programmes, quickly grasp the essentials of this approach to scenario building. The individual measures proposed in the scenarios are normally an exposition of trendy ideas. What makes the best scenarios interesting is the "What-Who" exploration. Planning seldom considers actors and actor collaboration to the same extent as measures, and the same applies to futures studies' scenarios (Wangel, 2011). If not articulated, the perspective of agency will unreflectedly be "business as usual". Thus the student scenarios explore social or socio-technical innovations in a way that planners do not do. Furthermore, the students' own assessments indicate that this approach identifies a larger freedom of action of local actors than is normally assumed. Thus the scenario building projects on the whole have been successful in contributing to the Master Programme's aim of going beyond today's practice.

4.3 Media Technology & Sustainable Development

In the fall 2012, one of the authors of this paper gave a course on sustainability and media technology for 1st year masters' students of Media Technology and Media Management. Many, if not most, of these students have not thought about sustainable development (SD) or encountered SD in previous courses, and they typically perceive the connection between ICT and media technologies on the one hand and SD on the other hand as tenuous. Previous experiences has showed that computer science and media technology students (and professionals!) not seldom have a hard time imagining other futures than a continuation of the last 50 years of exponential development in the field of computing (Moore, 2006) extrapolated into the far future.

Future studies can in this context "open up" computer science to the future and to the social imagination. The course in question presented two very different future scenarios to the students; a "vanilla sustainability future" where current sustainability challenges can be solved, not the least through smart application of ICT and media technologies, and a "doomsday sustainability future" where we instead will have to face climate change, resource depletion or other "undesirable" scenarios (Pargman & Eriksson, 2013). Students have an easy time imagining the less imaginative business-as-usual vanilla sustainability scenario – which more or less "closed

the future" by *not* pointing out possible uncertainties, by glossing over tensions between different perspectives as well as the normative dimensions of sustainability and of business-as-usual both today and tomorrow. "Doomsday sustainability" on the other hand makes large demands on students in terms of accepting an alternative worldview and opening up the future to many dimensions of uncertainty (including the presence or the possible absence of computers or the Internet in a bleaker, more challenging future).

The use of scenarios, speculative design and design fictions is not unsual in computer science and these scenarios – sometimes seemingly taken straight from the pages of science fiction (Dourish & Bell 2008) – can be very influential in moving researchers' and developers' imagination and in shaping the direction of research. The idea of "ubiquitous computing" (anytime-anywhere), computer scientist Mark Weiser's early and evocative vision (1991; 1993) of a high-tech future where computer power has become an invisible abundant utility (much like electricity today) is a case in point. Such unproblematized futures hardly ever acknowledge any messy here-and-now-problems and have justifiably been criticized (Bell & Dourish 2007), but the issue of how to systematically present critical perspectives and integrate them into ICT and media technology education has unfortunately not been explored to the same extent.

In the course in question, the students oscillated between despair and hope (Pargman & Eriksson 2013). A barrage of different and often contradictory course materials (e.g. TED-talks by both "pro-grown" and "beyond-growth" speakers) force students to integrate and test the implications of resulting images *before*, and to discuss and defend them *at* the weekly seminars.

One example is a seminar assignment that took as its starting point the uncontroversial observation that "planned obsolescence" or even a "gadget death wish"[2] has been identified as a widespread and severe sustainability problem especially within the ICT and consumer electronics sectors. Equally uncontroversial is the parallel observation that so-called "patent trolls" (also called "non-practicing entities") nowadays buy up patents, sit on them and when the opportunity arises sue (for example) small start-up companies for patent infringements, thereby hindering innovation not the least in the ICT and consumer electronics sectors. But are patent trolls then not doing what every true environmentalist would want by decreasing the speed of innovation and increasing the costs and the price of the finished product – thereby saving resources and emissions? By allowing, or even forcing students to wrestle with not just "the solution", but also "the problem", by exploring and testing causality and dependency, ethics and values, innovation and conservation, we seek to promote a kind of learning rarely included in engineering education.

Despite the tough challenges we set for the students, the results or the course (in terms of ability to tackle complex, fuzzy problems and in terms of intellectual growth) surpassed our expectations. Beforehand we feared that (a sizable part of the) students would resist being challenged, but we instead experienced a willingness and sometimes even a hunger on students' behalf for exploring (sometimes radical) alternatives to the dominant vision of the future.

4.4 Industrial Design

In the fall of 2012 one of the authors of this paper introduced futures studies for sustainability in a course for 3rd year students in Industrial Design at Konstfack – the University College of Arts, Crafts & Design in Stockholm, Sweden. Here ten students were commissioned to develop

[2] "Gadget death with", i.e. wishing that your smartphone will stop working the week after the new, more advanced model has been launched (Walker 2011).

design proposals for products, services or systems that signified a future where sustainable lifestyles had become the norm. The reason for inserting futures studies into this course was to promote a deeper understanding of what demands the challenges of sustainable development puts on design, and how these can be handled.

The design brief handed out to the students included a few but central starting points and demands. Firstly, their design proposal needed to address a major sustainability problem. Secondly, the proposal needed to make a substantial contribution to decrease this problem, in a way that did not cause any obvious negative effects for other sustainability issues. Thirdly, with the aim of showing a future where sustainable lifestyles are normalised the proposals needed to be represented in a way that did not focus only on material and technical details but that also integrated them into the context of everyday life. The course was introduced by a lecture in which a target-oriented futures studies approach (backcasting) and the major environmental challenges society faces were explained briefly. The students were also introduced to the backcasting study "Images of the Future City" (Höjer *et al*., 2011) in which six scenarios of a more sustainable Stockholm are presented, and were encouraged to use this as a backdrop to their work.

After ten weeks of tutor-supported work the students presented their final design proposals.[3] With few exceptions the proposals clearly fulfilled the requirements specified in the design brief; the proposals addressed one or more major sustainability problem, had a clear potential to abate these and were outlined and presented in a concrete way and integrated into an everyday life setting. The proposals differed widely both in terms of what type of changes that were suggested (physical/ technological, service, knowledge, values and habits) as well as the sustainability areas addressed (food, buildings, health, transport, consumption and education). While most proposals focused on one sustainability issue only, the majority included more than one type of change, for instance a combination of new technology and a change in values.

The proposals also varied in terms of how imaginative they were, i.e. to what extent they diverted from what the students saw as realistic. It was a most rewarding (and painful) experience to witness how the students struggled with the seemingly internalized urge to create something realistic while at the same time being commissioned to create something radically new. With this in mind it is very interesting to see that many of the students, in spite of their ambitions to come up with something radically new, ended up with proposals that they after a while realized already existed. Adding to this tension was the uncertainty introduced by designing for a future that was very much open. One of the first things you need to learn as a design student is to "trust the process", i.e. to cope with the uncertainty of not knowing where a specific project is heading. In this project it was not only the project but also the context that was uncertain, which meant that the students had to 'trust the process' in an even more fundamental way than they had been doing before. While this was perceived as highly demanding, on the verge of "impossible", the students did recognize that this openness made them more aware of the importance of context. Since there was no context formulated they could not take this for granted, and in the process of developing a project specific context their assumptions about this became visible and thus possible to scrutinize and alter. In this way the relationships between products/services and society and people became clearer. Asking the students to decide on their own sustainability problem and solution also resulted in that they

[3] All proposals can be found at the project website www.greenleap.kth.se

needed to explore and manage interrelationships, system boundaries and complexity in a more active way than when presented with a ready-made case.

5 Concluding Discussion

In this paper we have introduced futures studies as a tool for ESD and presented some examples of how this can be carried out. Futures studies methods work well in a problem-based learning setting (PBL) in which students are to define and elaborate both problems and solutions. They support this by way of opening up the "design space" through not restricting solutions to already existing and socially accepted technologies and values. At the same time the openness and complexity of the issues at hand also calls for careful tutoring and help by delimiting the projects so that they do not become too overwhelming. One of the key challenges of using futures studies methods concerns creating a learning environment that is challenging at the same time as being perceived as safe. This is essential as students who do not think that they will be able to succeed tend to adopt a surface learning approach (Biggs & Tang, 2011:26-35.). Since the students' ability to cope with uncertainty varies both within and across courses and classes there is no single solution to how to guide the students through the phases of sometimes very deep uncertainty and doubt without delimiting their imagination, creativity and innovation. Still, through acknowledging the students' feelings of uncertainty and doubt and letting them know from start that this is something that will occur, that it is an un-avoidable part of the process, and that students from previous cohorts have experienced the same and yet managed to succeed, this becomes less of a threat. Moreover, it also paves the way for students to communicate when the uncertainty becomes too deep to handle.

The potential contribution of futures studies methods have also been analysed in respect of how they relate to the knowledge, attitudes and skills (KAS) engineering students need to appropriate to better understand and contribute to sustainable development. These include taking on complex and "fuzzy" problems, and, related to this, to define both problems and solutions; to work inter-disciplinary and integrative; to address multiple time perspectives, and related to this, to manage uncertainty; to make use of imagination, creativity and innovation so as to open up the design space; and to acknowledge the ambiguity of sustainable development by way of identifying not only synergies but also conflicts and through reflecting on and discussing ethics and values.

However, given the diversity in futures studies approaches it is important to be clear about what the key learning outcomes are as this is decisive to the relative focus on methodological stringency, coverage and/or depth of issues, and ways for presenting and reflecting on the process and results.

The statements put forth in this paper builds on the authors own experience as teachers supplemented with data from course evaluations, exams and discussions during seminars and in more informal settings. However, to further strengthen the arguments made in this paper there is a need to quantitatively and/or qualitatively assess how and to what extent students' perceptions on sustainable development have changed as a result of the courses. In conclusion, however, we think that futures studies have a lot to contribute with in regards to ESD, and see great potential to further explore and expand this in different educational situation.

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