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Is Progress to Sustainability Committed Engineers Stalking?

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Abstract: Engineering Schools were among the first to address the challenge of Sustainable Development, and integrate Sustainable Development into their curricula. This paper identifies a tendency that this progress is stalking. Main factors are an increased tendency to train more narrowly specialized engineers, while specialized SD programs sometimes became an alibi to remove SD course from the major programs. Broader engineering programs are required for mainstreaming SD in engineering education.

Key words: engineering education, interdisciplinarity, specialization

1. Introduction

Since the publication of the Our Common Future, 31 years ago, sustainability problems have not vanished, on the contrary. The "ozone hole" has more or less been healed, but regarding climate change, resource depletion, and declining bio productivity and biodiversity no signs of a transition to a new equilibrium can be observed. Despite an unavoidable exception, there is increasing political support for taking action.

In the past three decades, it has been repeatedly claimed that engineering plays a key role in solving these global problems: a strategy solely based on austerity cannot solve these problems, given the fact that the major part of human population still lives in poverty. Engineering Education in Sustainable Development, a conference series that started in Delft, 2002, has been based on this conviction, and emphasized the importance of teaching strategic competencies in order to gear innovation to sustainable development. However, in the midst of a growing societal recognition of these problems, progress of EESD in engineering seems to be stalking. Frontrunners have sometimes cut their efforts, and SD courses often still play a marginal role in the curriculum.

This paper analyses this process and claims that it results from historic trends leading to more specialization and less emphasis on societal context in the engineering curriculum: the T-shaped engineer tends to become an I shaped engineer.

The paper will illustrate this by analyzing trends in recent engineering education. The paper is intended as a start for a discussion how we could boost progress in EESD.

2. Engineering Education until the 1980s

Traditionally the key to becoming a respected engineer was to gain experience. Until the 19th century, engineers learned the craft by apprenticeships. Although a university mathematics course could be helpful, the craft of engineering was learned in practice (Lintsen H., 1985). The foundation of engineering schools in the 19th

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century implied a revolution for engineering. Engineering education became based on rationality and science, instead of being based on tradition and experience. Many of the new 19th century engineering societies demanded that their members should be trained “scientifically”, to underline the break with the past (Mulder K. F., 1997).

However, there were many problems that could not be calculated: engineering designs were in practice often not based on exact calculations, but calculations with additional safety factors that emerged from practice. In this way fatigue and wear factors had to be dealt with, etc. But quantification became an important feature of the engineering paradigm. Especially designers that were dealing with features that were hardly quantifiable (beauty, user friendly, etc.) often met disdain from their colleagues. For example “Psychology” was considered unscientific, and should be kept out of engineering education (De Jong F., 1992). However, the soft features made their way into engineering, mainly as this was a key factor in turning engineering design into reality. It is fascinating to see how many bright engineering ideas failed in the Soviet Union, due to the inability to adapt engineering designs to “soft” demands (Graham L., 2013).

Ever since its inception as an institutionalized profession, engineering branched out in an ever increasing number of specializations: Mechanical-, Geological-, Agricultural-, Industrial-, Chemical-, Electrical-, Physical-, Architectural-, Maritime- and Aerospace- and Design-engineering followed. Moreover, by the general scientification of education, the educational programs of engineering became narrower, more theory-, and less practice oriented.

3. Engineering by the end of the 20th Century

Massive and cheap computing removed several of the barriers for improved engineering design: design features could be computed, and maintenance and user experiences could be registered in data bases and evaluated. “Modelling” replaced the craft of experimenting and full “mock-ups” were hardly needed for design evaluation. Tradition and experiences of the past were hardly needed anymore for good engineering design, and so “apprentice” elements in the engineering curriculum were diminished or completely disappeared.

However, the controversy regarding nuclear power, that emerged in most industrialized countries, showed that engineering design based on this “scientific rationality” was not unproblematic; in fact scientific rationality’ often coincided with predominant values in society (Nowotny H., 1979).

However, new values could come into play in engineering designs and old ones could be contested. Engineering became far more part of societal force fields, and various controversies emerged on engineering designs (airports, motorways, acceptability of food additives, agricultural chemicals, fluoridation of drinking water, etc.) (Nelkin D., 1974; Nelkin D.,1979; Mazur A.,1981; Mulder K. & M. Knot, 2001; Hicks J., 2011). However, these controversies were often just neglected by the engineering community, as engineers often perceived them as being based on ignorance.

The increased flexibility that computers and science created for engineering design, as it was no longer bound to forces of tradition implied that engineering designs became the centerpiece of societal controversy. Instead of being perceived as the great force of progress, engineers were often portrayed as irresponsible nerds.

4. Our Common Future and its reactions

After the Brundtland committee presented “Our Common Future”, the engineering community reactions were not very positive: “another report bashing technical-industrial progress…”. However, also soon other reactions showed up. Contrary to the wave op environmentalism of the 1970s, the analysis underlying "Brundtland" was not one of "environmental protection" but one of being able to provide for mankind in the long term future[1]. Such a long term planning perspective fitted to the mathematical model based planning perspective of engineering.

Backcasting was embraced as a strategic decision making method to take the (future) limits of planet earth as a starting point for planning (Robinson J. B., 1988; Robinson J. B., 1982). The method created an interesting controversy between what could be determined as

- a planning approach, taking Sustainability principles as leading principles in order to derive a sequence of planning actions (Holmberg J. & Robèrt K. H., 2000).
- and a decision-making approach aiming at bridging the divides between engineers and societal stakeholders, aiming at sketching long term options in order to trigger productive interaction (Weaver P. et al., 2000; Quist J. N., 2007).

The first approach to backcasting could be determined as "engineering planning with Sustainable Development as a core value set" while the second approach could be determined as "Strategic and interactive decision making on technology for SD"

The first approach is therefore a traditional expert based approach that is in line with the role that engineers have long played in society. It takes SD a given external goal. In the second approach, engineers take a new role, aimed at informing stakeholders on technological options and, creating interaction in order to reach consensus regarding socio technical development pathways. This involves a new role for engineers; a role that does not only involve expertise but also democratic leadership.

In other words, the difference is between "Engineering the future from Sustainable Development values" versus "Jointly engineering the future, based on Sustainable Development and other values". It is a difference between focusing on outcome and focusing on process; a difference between a traditional expert promoting inescapable solutions and the new expert, providing expertise as input for dialogue….

In highly educated societies, dialogue and interaction are important values. However, a scientific discipline has its own social mechanisms that keep the discipline together, the paradigm (Kuhn T. S., 1962). This also applies to engineering. Upon entering engineering schools, engineering students are increasingly inclined to give up their societal orientation, and define themselves, and their engineering designs, as neutral tools. Engineering education is in fact not just learning theories, facts, and design but also the initiation in a disciplinary paradigm (Cech E. A., 2014; Mulder K. F., 2017).

5. Changes in Engineering Education

The Bologna process created a strong divide between Bachelor and Master Programs. This created options for another wave of new specializations, this time at the Master level. Only few MSc programs were created that broadened the scope of engineering by adding new perspectives to engineering (e.g., Industrial Ecology (Korevaar G., et al., 2004), Sustainable Energy, or Innovation Studies (Salcedo Rahola T. B. & Mulder K., 2011). This new engineering programs, bridging various fields, were embraced by SD seeking students and managers, that aimed at combining model based analysis with practice oriented action.

[1] Of course one might argue that ultimately, providing for mankind is only possible if the environment is well protected, and the environment can only be well protected, if the number of people is limited and people are provided for.

The general branching out of engineering into more specialized engineering degrees was accompanied by the large scale introduction of “minor programs” and “exchange semesters” in BSc as well as the MSc programs. Deeper specialization created options for being admitted to MSc programs, and an exchange as an MSc student often implied participating in specialized research.

This development of at one hand increasing specialization and at the other hand new programs that aim at bridging various fields of engineering might be worrying for traditional engineering:

-A narrow specialization can only be legitimized by emphasizing the unique knowledge value of the program, i.e. negating the value of general knowledge

-The existence of MSc programs that bridge knowledge fields, can act as an “alibi”: students that seek general knowledge might opt for that program, so the subjects do not need to be included in specialized MSc programs.

The existence of new MSc programs that bridge knowledge fields might draw SD minded staff attention to that program, instead of drawing attention to implement general change in specialized engineering programs.

My own university, Delft University of Technology is a perfect example. In 2000 DUT offered 12 MSc programs to its students, some of which contained several “tracks”. Nowadays, this university offers 83 MSc and “tracks”, all advertised in an equal manner, to express that these are equal specialization options (Delft UT, n.d.).

Academic education has experienced various debates in recent decades. At the one hand, access to higher education has been curbed by deteriorating support schemes. At the other hand academic education has been promoted as a key factor in international competition. As a result, academic educating became more geared to demands of the labor market.

The diminishing freedom for students was compensated by the introduction of “minor” programs. The intention was that students could develop an additional qualification. In practice however, such minor options were often used for being admitted to specializations that were in high demand, i.e. as increased specialization options.

The result of these developments was that engineering students were, during their studies, increasingly focusing on their professional qualification. Education became less a matter of personal development and far more an issue of obtaining a ticket for a career as an (engineering) specialist.

6. Stalking Progress to EESD?

In many engineering schools modernizing engineering education seems to be stalking. For Sustainable Development no hard numbers are available. However, the landscape does not appear to be very flourishing. Educational reform initiatives do not grow and every now and then there is a setback. Moreover, related initiatives to strengthen linkages between engineering and societal developments are not thriving: For example, despite many efforts, the number of female engineering students hardly increases in the last decade (Microsoft Corporation, n.d.; Jansen M., 2015; Yoder B. L., 2016). New interdisciplinary MSc programs like Sustainable Development, Industrial Ecology, Sustainable Energy Technology, Sustainable Engineering, Environmental Engineering, etc., have established themselves in the academic landscape. Initiatives with high PR value are cherished at engineering schools as long as they bring good publicity, but the socio-technical challenges that it takes to actually implement novel sustainable systems are generally neglected.

In principle, competition for students might lead to increasing the SD content of established engineering programs as freshman and sophomores are attracted by SD. However, SD is sometimes banned from programs, as SD minded students might be referred to electives from other programs, instead of implementing SD in the own program. Given the strong tendency to focus programs on technological specialty (Cech, 2014), such a reaction might even be far more obvious.

An expansion of the efforts thus far is required if we want to go beyond the single green add on course. Curricula should be rebuilt give the overriding priority of reducing greenhouse gas emissions, developing a circular economy, and providing for all on this planet.

Academic engineering has taken the lead in education for SD, although progress is stalking. Vocational education is lagging behind and should now rapidly sustainabilize. For example, installers play a crucial role in the energy transition (Brezet J. C. & Silvester S., 1984). Installers of heating and cooling equipment often hardly know of fossil free heating and cooling alternatives.

7. The Future of Engineering

Nowadays designing engineers should design “value sensitive”, i.e. designers should perceive their designs not as neutral solutions for a given problem, but as an intervention in society, that can be assessed according to various different value systems (Friedman B., P. Kahn & Borning A., 2002; Van den Hoven J. ,2007). The impacts of engineering might affect human values. But what are these values, and who weighs them? The engineer him/herself? Of course it would be an advantage if engineers would be able to make such value analyses to evaluate their designs. But would it make much difference?

The key is not to involve all relevant values in the engineering design process and present that to stakeholders, the key is trust: to show transparently how different values affect the outcome of the design process, i.e. the key is interaction with stakeholders. Engineers should have the ability to work with stakeholders, who put forward their own values.

The designing engineer is a gatekeeper that has to take the responsibility that the design “works”. In that respect, the engineer bears a specific responsibility, a responsibility that should be based on design expertise, and not on “alternative facts”.

Expert communities have been “deconstructed” as being not just sharing expertise, but also sharing specific values and as being susceptible for specific interests. This has sometimes contributed to a conviction that expert reasoning is only equally valid as all other types of reasoning as it is just “a representation of interests”. If such distrusts to experts would be widespread among the citizens, it could lead to terrible accidents.

In debates on Science & Society, scientists have been assigned the role of being honest brokers. In parallel, engineers should be able to play a similar role in regard to the public: being able to show the alternatives that are available and their impacts (Pielke Jr R. A., 2007), thereby facilitating an open and democratic discussion on our common future.

8. Conclusion

Engineering for Sustainable Development does not just require an engineer to have knowledge of sustainability issues, it does not just require new values, it requires foremost a new identity as an engineer: an identity as an expert, who is an honest broker in technological design, and serves the pathway that our communities decide to take towards Sustainable Development.

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