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Education in Energy Engineering Based on Industry Needs

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Abstract

There is an increasing demand on education in energy and environmental engineering, following the trend in society towards increasing sustainability including economic, social and environmental aspects. Altogether this field is considered imperative for competitiveness in the future for many companies and at many markets.

This paper addresses these issues by an investigation of industry needs prior to and during development of a new energy engineering profile (curriculum) of as a part of a Masters program in Industrial engineering and management. Also student interest and expectations are taken into account, and subsequently the profile is evaluated.

In general, both industry and students were positive to the proposed profile, which was therefore started. Students currently following the profile are in general satisfied, including the 30 % studying abroad. Many of the bachelor projects carried out abroad are located in emerging countries which highlights the competence deficiency in countries outside the industrialized parts of the world.

Introduction

The general trend in society is towards increasing sustainability, including economic, social and environmental aspects. Sustainability is also related to corporate social responsibility (CSR), which can be referred to as the industry equivalent for businesses that intend to prosper in the long run[1,2], and is highly reflected also in engineering education[3].

There is an increasing demand on education in energy engineering in a broad sense, including e.g. environmental technology and energy systems engineering[4]. Although the number of courses and programs in the field has grown substantially the last 10-20 years, it appears to be a shortage of engineers in the field. Reasons include increased focus on the green-house effect, a rapid development in emerging countries with a lack of resources and knowledge to handle even relatively basic energy and environmental problems. A further discussion of the challenges associated with sustainability and engineering education can be found in[5,6].

Another important factor is the value of companies and organizations to profile themselves as sustainable and “green” to attract customers, in addition to the demands put on companies by regulations. All in all, the importance of energy and environmental engineering as a base for sustainability and competitiveness is growing. In fact, over 90 % of global company CEOs view sustainability as imperative for their companies’ success in the future[7], and small and medium sized enterprises (SMEs) are often forced to educate their personnel[8].

This paper presents the development of a new energy engineering profile that constitutes about one third of the curriculum of a 5 year Master's program in Industrial engineering and management at Linköping University, Sweden. During planning of the program, it was decided to investigate and take into account the industry needs today and in the future. The aim was also to address the different challenges of sustainability in different parts of the world. During this work, aspects of industrial ecology have been incorporated, inspired by for example Biswas (2012)[9]. Before the profile was started, the student interest was investigated among the students already at the program – if the interest had been low, it could be argued that the resources were better spent on the other profiles.

The investigations showed that both industry and students were positive to the profile. The industry experiences a clear problem to recruit personnel in energy and environmental engineering today, and forecast a worsening of the situation. The profile has now run for two years and is currently the second largest on the program attracting close to 30 % of the students. The students are in general satisfied with the content and outline of the profile and especially the bachelor project. On the negative side there is some critique regarding course overlap and that some minor specific parts of the courses are not at a sufficiently high level, although this might be due to the overlap between courses.

Context of the study

The program of interest in this study is a 5 year Masters program in industrial engineering and management is quite large (approximately 230 new students each year) at Linköping University in Sweden – a well-recognized university in Europe with some 25,000 students of which about 50 % study engineering. Approximately 50 % of the students at the program are females.

The program has a traditional curriculum for the first 2 years, including courses in Mathematics, Mechanics and Computer programming, together with introductory courses in industrial engineering. After one and a half years, the students chose one of five engineering profiles; computer engineering, bio-technology, mechanical engineering, electrical and systems engineering and finally the new profile in energy engineering. The engineering profile is to some extent a curriculum of its own, and must contain at least 70 credits (one full study year equals 60 credits), thus making up about a quarter of the program. Of the 70 credits, 15 are dedicated to a bachelor thesis. The students also chose one industrial engineering profile, for example marketing, financing or logistics.

Investigation of industry needs

Early in the process of developing the profile, several months before it was actually decided to start it, there was a consensus of the board of the program to involve industry in the design of the profile. The board consists of 12 persons of whom 6 are teachers/researchers at the university, 3 represent the students and 3 are representatives from industry/society; at that time, the industry/society was represented by SAAB Aeronautics, Ericsson and the national transport administration.

There were several reasons for the decision of a formal investigation of industry needs instead of just relying on competence within the board. The energy engineering sector is large, diversified and develops quite rapidly, and therefore a relatively large number of companies were necessary to cover the sector's needs and challenges. Furthermore, two important types of businesses, energy producers and heavy industry using a lot of energy, were not represented in the board.

The most important aim of the study was to investigate the present and future need of competence in the energy engineering field, and how this should be addressed in the curriculum and courses. The focus is on the need of *industrial* engineers with sustainability competence, as a complement or alternative to engineers from other disciplines, for example mechanical or electrical engineering.

The investigation of industry needs was mainly carried out by two senior students at the Masters program with experience and skill in similar investigations under supervision of an Associate Professor at the university, and by the author of this Paper. It was decided to perform the investigation using a combination of questionnaires and semi-structured interviews.

To cover a wide range of companies, 30 companies in three categories were included:

1. Manufacturing industries using a lot of energy, e.g. paper and steel industries (examples: Ovako, Sandvik, SSAB, Holmen Paper).
2. Energy producers/owners of power plants and small companies working with e.g. renewable energy or technologies for energy savings (examples: Vattenfall, Tekniska Verken, Swedish Biogas, Mjölby Svartådalen Energi).
3. Consulting firms (examples: Ångpanneföreningen, McKinsey).

The intention was to have an even mix of small and medium sized enterprises (SMEs) and large companies. The classification of companies follows the definition by the European Commission, stating that SMEs are companies with a turnover less than 50 million Euro. As it turned out, however, all companies in the first category and most in the second are large, and therefore only 7 of the 30 companies in the investigation were SMEs. The companies were chosen based on connections between the board/university and former graduates from the program now working at the respective companies. This made sure that the persons interviewed had an own experience of the particular program including its organization and profiles, which was considered a key to profitable interviews.

As mentioned before the interviews were semi-structured, meaning that a few open questions were asked, followed by a discussion of the topics during 15-30 minutes. Examples of the questions asked were:

- Do you at you company have a strategy for energy and environmental sustainability?
- Is there a need for industrial engineers specialized in energy engineering?
- What kind of competence in the energy field is most important for an industrial engineer?

- Do you have experienced a lack of knowledge in the energy engineering field at your company the last 6 months?
- How easy is it to recruit personnel with competence in the energy engineering, and how do you expect this to change over a 10 year period?

A summary of the investigation was presented in a short report, and orally presented for the board followed by a discussion. Despite the variety of companies, it was interesting to find a clear similarity in their response. Most of the companies had a strategy or at least a clearly defined intention to work in a sustainable way. Sustainable was mainly interpreted as "energy and environmentally sustainable", although about 40 % of the companies included social and ethical aspects as well. It should be noted that the proposed and later adopted name of the engineering profile is "Energy engineering", which may have biased the response towards an energy and environmental focus.

Practically all companies considered it important for the industrial engineers focusing on energy engineering to have a broad expertise including various aspects, rather than focus on a narrow part of the field. This is more or less as expected, since the industrial engineers are not often technical experts. For the energy companies, fundamental and specific engineering knowledge was considered important as well, especially in the SMEs.

About half of the companies had had some problems recruiting personnel with energy engineering competence, although it was difficult to pin-point what specific kind of competence that was lacking. Some companies had not experienced problems with recruiting (to the knowledge of the person interviewed), and some companies had not recruited new personnel. An interesting finding was that over 80 % of the companies believed that it would become more difficult to find personnel with energy competence on a 10 year horizon. It should be noted that the persons interviewed worked as traditional industrial engineers at different levels and with different focus (e.g. marketing or logistics), and therefore had not first-hand insight into the recruitment of new personnel.

Industries mainly working in emerging markets and/or with relatively new technologies pointed out the importance of a curriculum that not only includes a technological perspective, but also addresses e.g. commercial and economical aspects of energy and environmental engineering. This was particularly evident among the smallest companies, probably reflecting the less specialization of the personnel in such companies. It has earlier been shown that SMEs are finding it necessary to educate their personnel in e.g. environmental issues to be able to stay competitive[6].

Some of the companies were acting or planning to be active at emerging markets in e.g. Africa and South America. In such cases, it was interesting to note that the companies valued personal qualities and characteristics together with experience from such countries/markets.

Student interest and motivation

Before it was decided to start the profile, student interest in the profile was investigated by a questionnaire sent by E-mail to all students currently registered on the second year of the program. These students were chosen since the choice of engineering profile is carried out during the second year. As is often the case with this kind of surveys, the response rate is quite low; in this case it was about 30 %, which to some extent reduce the validity of the survey. As shown by Figure 1, there was a clear interest in the profile with about one third of the students stating that they would choose it if it was started.

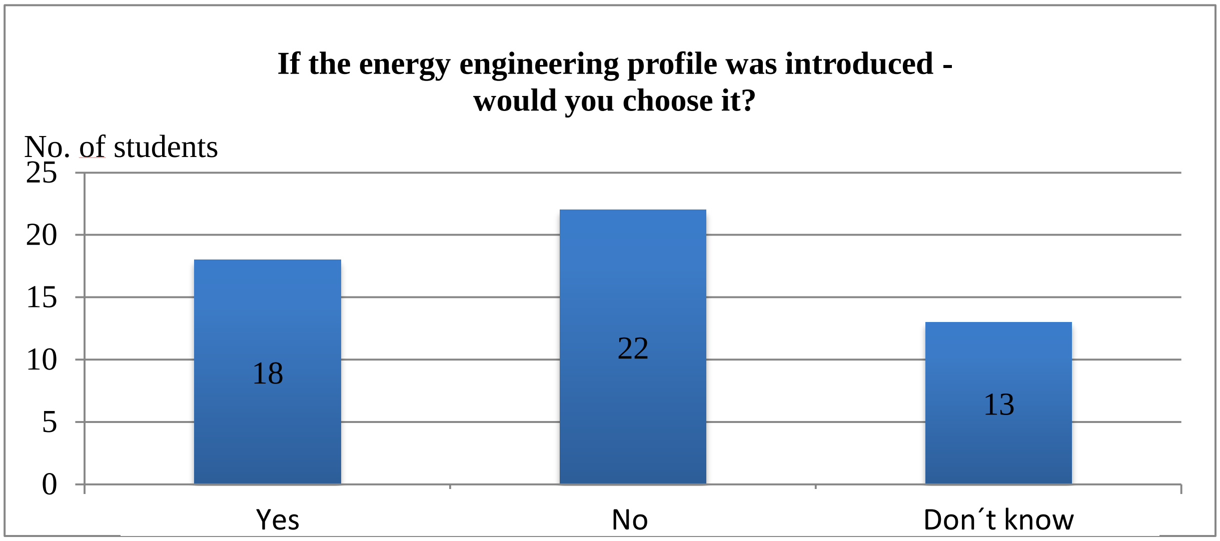

Figure 1: The figure shows student interest in the new profile among second year students (before the energy engineering profile was introduced).

Another part of the survey investigated which of the currently available profiles that the 18 students interested in energy engineering was going to choose if the energy engineering profile was *not* started. As shown in Figure 2, most of these students would choose mechanical engineering. Some of the profiles had further specializations within the profile; in the case of mechanical engineering, 2 of the specializations were “Energy systems” and “Environmental engineering” which explained the interest in mechanical engineering among the students with interest in energy and environmental engineering.

Based on the positive feedback from the industry and the large student interest, it was decided to introduce the energy engineering profile in 2012. So far, the students have chosen a profile three times since it was first introduced. The first time, about 20 % of the students chose the profile, which is less then then 30 % indicated by the investigation prior to introduction of the profile. The second and third time, close to 30 % chose the profile, very close to what was prediction by the investigation. The relatively few students choosing the profile the first time can be explained by a concern for a new and “not yet proven” profile, and by apprehended difficulties by finding relevant courses abroad (about one third of the students at the program study abroad, often between half a year and a year).

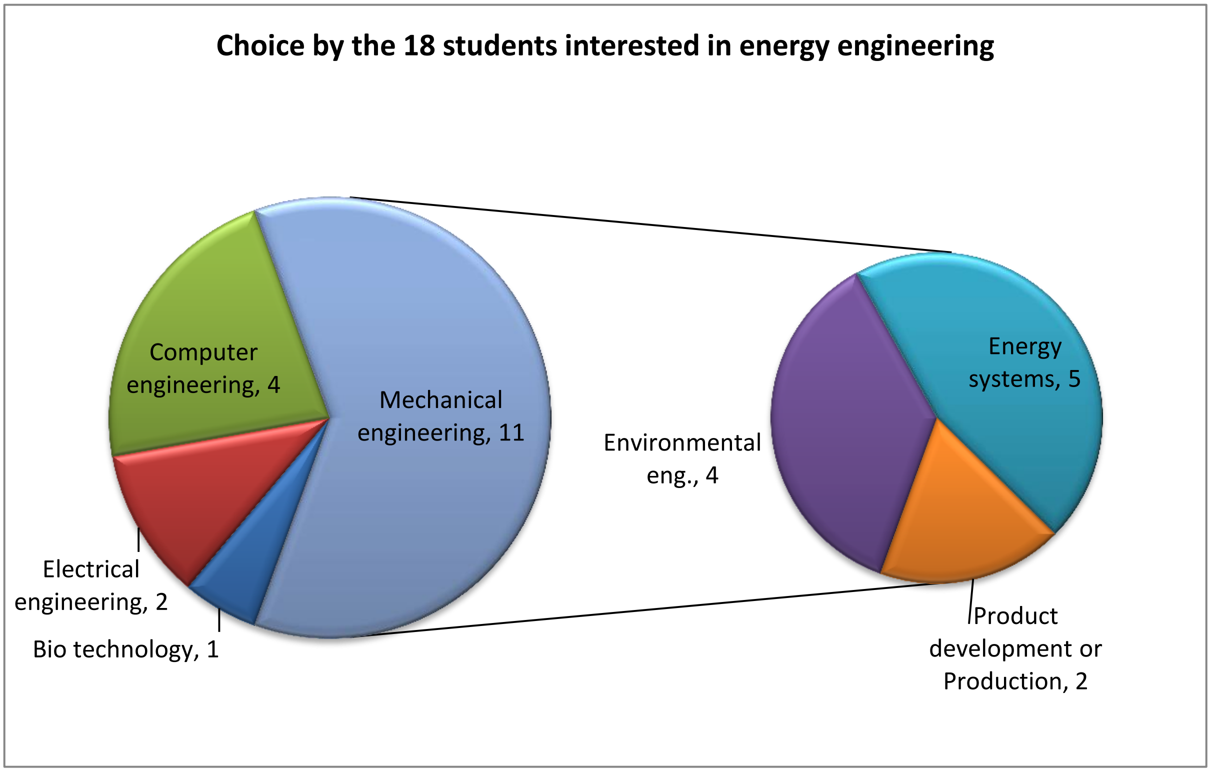

Figure 2: The left hand side of the figure shows what engineering profile the 18 students interested in energy engineering would choose if the energy profile was not started. Among the 11 students that had chosen the Mechanical engineering profile (right hand side of the figure), 5 were interested in Energy systems, 4 of Environmental engineering and only 2 of the “classical” mechanical engineering specialization (product development and production).

Outline and evaluation of the energy engineering profile and curriculum

The profile contains 5 mandatory courses corresponding to 4 full time weeks. The students always take three courses in parallel over a period of 10 weeks, thus taking 2 full time courses and 1 part time course. The energy engineering courses are always full time courses, and only one such course is taken in each 10 week period. In turn, the courses are

1. Applied thermodynamics and fluid mechanics. A traditional but very condensed course introducing the basic laws of thermodynamics, heat transfer and fluid mechanics.
2. Energy conversion. Technology and methods for energy conversion is introduced. There is some focus on renewable energy such as solar and wind power as well as bio-fuels but traditional conversion of fossil fuels is also included.
3. Environmental engineering. Introduces the relation between society and nature, and exemplifies environmental concerns as well as possibilities.
4. Energy systems. Focus on both local and regional perspectives on combined energy systems of suppliers and users.

5. Resource efficient product development and production. Starts with an introduction to structured product development methods, through energy and material management to production from a resource perspective.

Courses number 2, 4 and 5 are developed specifically for the energy engineering profile, whereas the others were already existing courses. After the above courses, all students carry out a bachelor project, either at the university in groups, or abroad individually or in pairs. Approximately one third of the students carry out their bachelor project abroad; so far the majority has been related to small-scale and/or renewable energy. Examples are the use of fuel cells in Japan, extended use of solar thermal power in Mexico and waste heat recovery from Diesel engines used for electric power generation in Tanzania.

The bachelor project for the students not studying abroad is carried out as a project based course at the university. The course extent is 12 weeks of which 10 are dedicated to the project. The additional 2 weeks contain traditional education supporting the project, primarily energy technology and product development methodology. During the first 7 weeks the course run in parallel with 2 other courses, followed by 10 weeks of full time work. The course attendants are early divided into groups of 5-6 students, who work quite self-dependent (without much teacher support). This is considered a very important part of the course, since both the course and the bachelor degree require proven self-dependent engineering skills. During the project part of the course (the last 10 weeks), each group gets a maximum of 1.5 h supervision per week.

The project task has so far been to design, build, test and analyze a prototype of a solar thermal system. Each group gets some equipment (a pump, 5 solar panel plates (1200*150 mm^2), 4 wheels and a glass sheet) and 200 Euro. The money can be used freely to buy material for the systems (e.g. sawn goods, pipes, pipe connectors, valves, a water tank etc.). Different kinds of demands are put on the prototype; it should perform well (generate warm water and keep the temperature high over time), but also be innovative, built with quality and esthetically appealing etc. There are also restrictions in terms of size, weight and cost. All demands and restrictions are summarized as an equation that give "points" dependent on how well the different aspects are fulfilled. Points are also achieved by saving some of the 200 Euro. Altogether, this gives a transparent and stimulating comparison of the systems, and also leads to a competition between the groups. The project is finally presented orally and in a report containing about 100 pages.

The profile has now run for two and a half years. During this time, all courses at the profile have been evaluated each time they have been given. This was carried out by a standardized online questionnaire developed by the university and used in most courses. The students can give written comments and grade various aspects of the course as well as the course as a whole between 1 and 5, 1 meaning "not good at all" and 5 meaning "very good". The students are satisfied with most of the 5 mandatory courses making up the first part of the profile, especially the course in applied thermodynamics and fluid mechanics that got an overall grade of 4.3. The course in energy systems only got a grade of 2.8, in part due to some overlap with the energy conversion course, a too low level of the course, and too many teachers that were not synced. The mean overall grade of the 5 courses was 3.5. Unfortunately the response rates of these surveys are quite low, about 40 %.

The bachelor course got an overall grade of 3.8 in the standard course survey, which is considered good having in mind that it was the first time it was held. The bachelor project as well as the profile as a whole was also carried out by a questionnaire distributed by the author of this paper to the students first enrolled, at the end of their bachelor project. The response rate was high, about 70 %. The overall grade of the course shows that most students were very satisfied with the bachelor project. Aspects particularly emphasized as positive were the multifaceted engineering approach and the opportunity to freely work on a large project. The project was also considered very relevant for the energy engineering profile.

In addition to the above, the student union evaluated the energy engineering profile including the bachelor project. One student attending the profile is elected to represent the other students and work together with the student union to evaluate courses, propose improvements and look after the students' rights. The student representative continuously follows up on the courses, and has an evaluation meeting with his/her fellow students at the end of each course. Based on this feed-back, another meeting is held where the student representative presents the feedback, proposed course improvements etc. for the teacher responsible for the course as well as representatives from the student union the board of the program. During this meeting, all parties discuss the course with the overall aim of improving the course. The courses are not only discussed as stand-alone courses, but also as a part of the engineering profile and the program as a whole.

The students are in general satisfied with the profile, although some "tuning" is necessary. There is some overlap between courses, especially between the courses "Energy conversion" and "Energy systems", but also between the bachelor project course and the course "Resource efficient product development and production". Some students thinks that the profile lack some "technology" and "engineering", and request more "traditional" engineering content like equations and calculations in thermodynamics and heat transfer at the expense of e.g. social environmental sustainability and energy systems. At present, there is no immediate plan to meet this request on a large scale (e.g. change courses), but some minor changes towards this aim has been undertaken within the present curriculum.

After the first 5 courses and the bachelor thesis, the students are free to choose relatively freely among a number of courses in the field of energy and environmental engineering. Examples of courses are

- Industrial energy systems
- Industrial ecology
- Gas Turbines
- Small scale renewable energy
- Biofuels for transport

No student has so far graduated from the Master´s program, but there is a quite large interest both nationally and internationally judged by e.g. the general interest from companies and by the offers of bachelor projects the students get.

Sustainability in industrialized and emerging countries

Education in this relatively new and rapidly growing field has so far not fully reached industry and society needs. This is true for industrialized parts of the world, but even more so in emerging countries/societies. There are however initiatives that counteract this disproportion. One notable example is the “Young Masters Program” which is an international educational course that connects teachers and students in different countries over the internet[10].

Most of the resources, knowledge and education is associated with, and kept within, the wealthy parts of the world even though the energy and environmental problems are worse in emerging countries. This may seem strange, especially since many energy and environmental problems are global rather than local. To some extent, this can be explained by the large divergence in pre-requisitions, demands and goals for different countries and societies, which is also intertwined with substantial cultural differences and complexities[11]. The conception of sustainability simply means different things in different parts of the world, and a lot of different factors affect the priority among sustainability issues.

As an illuminating example, the country of Rwanda is planning to double its electricity generation from 2014-2017 – this will be carried out in different ways, but the country’s very low GDP drives the production to the cheapest possible which often means burning of fossil fuel without exhaust gas cleaning. To give some perspective, electricity prices are as in Europe and the US, and fossil fuel like Diesel is as expensive as in Europe and about 50 % more expensive than in the US. At the same time, a worker earns about $2 a day. Despite these substantial differences between e.g. the US and Africa, is has been shown that no major differences in CSR (Corporate Social Responsibility) exists[12].

Students at the profile show a large interest in applying their knowledge to among others emerging technologies in developing countries – some students have already carried out projects in e.g. Africa (Rwanda and Tanzania) and in Mexico, and mainly associated with renewable energy. The students were financially supported by a national foreign aid agency. This is both interesting and inspiring, as there are many reports showing progress is such countries. In[13] for example, the rapid development in Southeast Asia is described. Fossil fuel is being changed to “cleaner and greener forms of energy”, for example from wind, sun and geothermal sources, but also bio-fuel as palm-oil (although there is some dispute over how sustainable this is).

Conclusions

Investigation of industry needs and student interest prior to introduction of an energy engineering profile at a Masters program in industrial engineering has been carried out, followed by an evaluation of the profile after 2 years.

There is a large interest and need of competence in this field both in Europe and in other parts of the world. The investigation showed that not only companies in the energy sector are positive to the profile, but also companies using a lot of energy (heavy industry) and consulting firms. For industrial engineers, most companies believe that a broad energy focus is preferred, especially for small and medium sized companies and companies outside the energy sector. About half of the companies had had problems recruiting personnel with energy competence the last year, and 80 % of the companies believed that the situation would worsen over a 10 year period.

Involvement of the "consumers", both students and industry, at an early stage has worked very well. The approach has contributed with fruitful ideas, and equally important with credibility that is hard to argue against for unbelievers during discussions of the profile before it was founded.

After 2 years, the students are satisfied with the profile as a whole and most of the included courses. There is room for improvements regarding e.g. overlap between courses. The students request some more traditional engineering content in the profile, despite that the large bachelor project is really seen as an engineering course. This is somewhat contrary to what the industry requests – industry highlights the importance for industrial engineers in the energy field to be quite broad and also include environmental and energy systems aspects.

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