BRIDGES AND PROBLEM SOLVING
Swedish Engineering Students Conceptions of Engineering in 2007

Mattias Wiggberg
Department of Information Technology, Uppsala University, Uppsala, Sweden

Peter Dalenius
Department of Computer and Information Science, Linköping University, Linköping, Sweden

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Abstract: Swedish engineering students' conceptions of engineering is investigated by a large nation-wide study in ten Swedish higher education institutions. Based on data from surveys and interviews, categories and top-lists, a picture of students conceptions of engineering is presented.

Students' conceptions of engineering, are somewhat divergent, but dealing with problems and their solutions and creativity are identified as core concepts. The survey data is in general more varied and deals with somewhat different kinds of terms. When explicitly asking for five engineering terms, as in the survey, a broader picture arises including terms, or concepts, denoting how students think of engineering and work in a more personal way. For example, words like hard work, stressful, challenging, interesting, and fun are used. On the other hand, it seems like the interviewed students tried to give more general answers that were not always connected to their personal experiences.

Knowledge on students' conceptions of engineering is essential for practitioners in engineering education. By information on students' conceptions, the teaching can approach students at their particular mindset of the engineering field. Program managers with responsibility for design of engineering programs would also benefit using information on students' conceptions of engineering. Courses could be motivated and contextualized in order to connect with the students. Recruitment officers would also have an easier time marketing why people should chose the engineering track.

1 INTRODUCTION

Engineering education in Sweden faces several challenges today. New groups of students are entering higher education (Furusten and Lundh, 2007) which challenges both the design of education and the pedagogical methods. In addition, the number of applicants to engineering programs has decreased during recent years (Inkinen et al., 2007). At the same time, several stakeholders see an increasing need for engineers (Maury, 2004; Kungl. Ingenjörsvetenskapsakademien, 2003).

The gap between the growing need for engineers and the shrinking group of applicants raises several questions. What do students think of engineering education, why do they choose to enter an academic engineering program and what makes them finish their studies? To explore questions regarding why students enter engineering programs, it is interesting to know what conceptions of engineering Swedish engineering students have. Thus, the aim of this study is to *find and describe what conceptions of engineering education Swedish engineering students have in 2007*.

Finding out what conceptions of engineering the students have requires a huge investment in data collection. Our empirical data comes from the nationwide Stepping Stones project, organized by CETUSS [1]. The Stepping Stones project was a unique data collection experience where researchers from ten Swedish higher education institutions were collaborating and gathered data from more than 500 students.

The the article is organized as follows. An introduction to the area is given through a literature review presenting material relevant to the current study. The data collection framework Stepping Stones is pre-

[1] www.cetuss.se

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sented followed by a section presenting and explaining the method used. Some key results from the analysis are then given and discussed. Finally, conclusions are drawn and directions and further work are suggested.

2 RELATED WORK

There is a growing body of literature on college students' understanding of engineering and engineering practice. The conception of engineering among student populations promises to be an important aspect, since it is likely that it contributes to knowledge on motivation among engineering students and perhaps the reluctance to undertake an engineering education.

(Mosborg et al., 2005) studied what advanced practicing engineers ranked as key concepts of design activities in engineering. Among other results, problem formulation and communication were ranked highest, while building was ranked among the least important activities. Creativity was ranked as neither important nor unimportant.

The (Extraordinary Women Engineers Coalition, 2005) reports from the Extraordinary Women Engineers project, a national US initiative that targets the question 'Why are academically prepared girls not considering or enrolling in engineering degree programs?'. Using online focus groups, in-person focus groups and online surveys they primarily targeted high school girls to learn about what they think about engineering, their career motivators and influences, and received and desired information about engineering. Findings from the study show that engineering is perceived to be a male field. The high school girls would like their jobs to be fun and at the same time they would like to make a difference. High salary and flexibility are also important. Finally, they want to get information on how identified important career motivators can be met by choosing the engineering track. This is not recognized to be the case at the moment (Extraordinary Women Engineers Coalition, 2005).

Conceptions of engineering of engineering students at the senior level have been investigated at the Center for Engineering Learning and Teaching at the University of Washington. In a word-association task technical knowledge was more recognized than issues such as communication, multidisciplinary teams, and global and societal context issues (Turns et al., 2000).

(Goel and Sharda, 2004) had both engineering students and professional engineers rank a list of activity verbs. Students were asked to sort the words according to how well they thought the activities increased their learning, engineers according to the activities' perceived importance for students. Words expressing activities that require higher order cognition (e.g. analyze, design) were ranked high in both groups. Another group of students rated the same words according to their frequency of use in teaching. Among the top words in this ranking, most concerned simpler activities (e.g. calculate, explain). Goel and Sharda draws the conclusion that while students and professional engineers agree on which activities an engineering education should focus upon, in reality the educational programs do not foster creativity, innovation and critical thinking enough.

(Loui, 2005) reports from a study where students in a course in Engineering Ethics were asked for the characteristics of an ideal professional engineer. Their answers fell into four categories: technical competence, interpersonal skills, work ethic and moral standards. Typical responses in the first category included creativity, innovation, solve problems and scientific knowledge.

We believe that the body of literature in this could become more complete by adding studies aimed at identifying students' conceptions of engineering. This is especially true for Sweden and Europe, and this is where our study fits in.

3 THE STEPPING STONES INITIATIVE

The Stepping Stones project is an extensive multi-researcher, multi-institutional study which aims to contribute in the area of engineering education research. The Stepping Stones project investigates how students and academic staff perceive engineering in Sweden and in Swedish education. The Stepping Stones study is situated uniquely in Swedish education and allows for exploration of a Swedish perspective on conceptions of engineering. The Stepping Stones project was based on a model of research capacity-building previously utilized in the USA and Australia (Fincher and Tenenberg, 2006).

The Stepping Stones data collection consisted of four tasks, two of which are used by this study. A web based survey, a critical incident interview, a photo elicitation interview, and a concept map task (Novak, 1998) were carried out using the explanogram technique (Pears et al., 2003). One aim with these different data collection approaches was to produce both quantitative and qualitative data with the intent to provide a basis for triangulation of data as a means to improve the quality of the results. Another important aspect was that by using different data collection methods we could get a richer data set. In the study reported in this article, where we want to acquire information about students' conceptions of engineering, we used two parts of the Stepping Stones data: interviews and survey responses.

4 METHOD

4.1 Data Collection

During 2006 and 2007, data was gathered by a web-based survey and through interviews from ten Swedish institutions. Students from different engineering programs where asked to fill out the survey and to participate in an interview session. Some students participated in both an interview and a survey, while others participated in only one of them.

The web based survey was adapted from the Academic Pathway Study (APS) survey (Eris et al., 2005). The survey consists of questions about factors that may be of importance in engineering. Examples of such factors include skills, identity, and education.

The survey has been used in many institutional contexts in the U.S. and has been analyzed for its validity (Eris et al., 2005). The survey was adapted to a Swedish context. Words were changed to Swedish equivalents, background questions not making sense in a Swedish context were removed and some new questions added. A pilot run of the modified survey was trialled prior to the full scale survey (Adams et al., 2007).

Nationwide, 521 students filled out the survey and 94 students participated in the interview session. The student cohort represented both freshmen and more senior students. The sample investigated corresponds to approximately 1.5 % and 0.3 % respectively of the total number of students in Swedish engineering programs autumn 2006 (SCB, 2006).

The participating students were widespread among different engineering disciplines, and in total 21 different engineering disciplines [2] were involved in the study.

For this study, we used only a small part of the empirical data from the Stepping Stones project, namely answers to 2 interview questions and answers to 1 survey questions, and the analysis was divided into two different threads. The first thread concerned data from the interviews. Here the interviewee's own words and conceptions about "real" engineering were analyzed. The second thread of analysis concerned the conceptions of engineering displayed in the surveys. Word frequencies and categories, or sets with similar concepts, are identified and reported.

4.2 Analysis of Answers from Interviews

Qualitative data used in this analysis was collected exclusively from the critical incident interviews. The critical incident interview starts with questions recalling a specific experience from the interviewee's past. A number of questions are then posed, aimed at revealing more information about the experience as well as its meaning for the interviewee. Critical incident interviews have previously been used by (Flanagan, 1954), (Klein et al., 1989), and (Klein, 1999).

A semi structured interview approach was used to elaborate on the answers given. Thus the interview began with a set of specific questions followed by opportunities for the researcher to probe or follow-up on responses from the participants (Kvale, 1997, p. 117).

The Stepping Stones interview script contained, among others, two different questions regarding conceptions of engineering at different points in the interview:

1. In a few words, what would you say real engineering is?
2. After everything we have talked about, what would you say engineering is for you?

In order to get as broad answers as possible to the question of conceptions of engineering, we have taken answers to questions 1 and 2 together as one data source, except in one particular case where we focus on the impact of the interview. As these questions appeared at the start and towards the end of the interview, conceptions of engineering recalled during the interviews are collected.

The answers to the two questions analyzed were extracted from the transcripts and a simple categorization of the transcripts followed. The method was inspired by qualitative text analysis, which is a standard method for analyzing text systematically, although the concept is used to describe a wide set of methods (Hsieh and Shannon, 2005). The general aim with qualitative content analysis is to "provide knowledge and understanding of the phenomenon under study" (Downe-Wamboldt, 1992). Qualitative con-

[2] Aerospace eng., bio-inspired and agricultural eng., biomedical engineering, chemical eng. (and chemistry), civil eng., computer eng., computer science, electrical eng. (and micro-electronics), geological eng., information technology, materials science and eng., mathematics, mechanical eng., interaction design, software eng., physics (and technical physics), systems in technology and society, energy eng., industrial economics, construction eng., other (less than 5 respondents in total, for example cognitive science and transport and logistics).

tent analysis is therefore more involved than merely counting word frequencies in a text (Weber, 1990). Qualitative content analysis has earlier been used in similar projects, for instance (Dolde and Götz, 1995) and (Eckerdal, 2006). Among many others (Mayring, 2000) has described qualitative content analysis and especially inductive category development, which is the method of finding categories that we have used in this study.

By analyzing the transcripts in a systematic manner, forming tentative categories centred on the research question of conceptions of engineering and revising them within a feedback loop, we deducted a set of well defined categories describing experiences of the phenomenon. No quantitative aspects where considered. Revision of categories in the feedback loop included testing the validity of categories and definitions by applying the tentative categories to the data. Categories were also merged and divided up during the analysis. Another researcher then verified the categories by the same procedure. The same categorizing process was used for question 2 and after some discussion, we found that the same categories as in question 1 also held for responses to question 2.

4.3 Analysis of Survey Answers

For this study, we have chosen to focus on one particular survey question dealing more explicitly with conceptions of engineering:

1. In the space provided, list 5 terms you would use to describe “engineering”.

Based on the responses provided, we cleaned the data and translated answers given in Swedish to English. Following this, the approximately 1400 answers were clustered in order to make the grouping easier. Terms with close semantically meaning were first put together. For example ’solving problems’ was grouped with ’problem solving’, ’creativeness’ with ’creativity’ etc.

This process of clustering and grouping the terms was performed by one of the authors and verified by the other.

5 EMPIRICAL RESULTS

In this section, we present empirical results from the survey and the interviews.

5.1 Engineering Terms from the Survey

The most frequently stated engineering terms from the survey are presented in table 1. Since the survey question did not offer any fixed terms to chose between, the number of different terms is huge. Hence, only terms with an occurrence of 1 percent or more, i.e. there being at least 14 listings of the term, are included in the table.

The terms stated by the participant in the survey, describe many different aspects of engineering. Personal aspects, *open minded*, *stubbornness* and *respected*, descriptions of the everyday life of an engineer, *frustrating*, *individual work* and *time consuming* are present side by side with terms describing the aim with engineering, for instance *constructing*, *inventions* and *developing*.

Problem Solving is by far the most common term used to describe engineering with more than twice as many occurrences as the runner up *creativity*. Among the top words, most are abstract descriptions general aspects of engineering. There are also a number of words describing the everyday work from a more personal perspective: *interesting*, *hard work*, *fun*, *high salary* and *challenging*.

Mathematics is ranked as third, but accounts for only 4.8% of the whole set. Apart from that, there are few occurrences of academic subjects, *physics* with 1.1% being the second most common word of that category. Words describing engineering processes include *developing* (4.1%), *analysis* (1.9%) and *designing* (1.1%). Aspects of engineering work include *team work* (2.5%), *project work* (1.3%) and *leadership* (1.4%).

5.2 Answers from Interviews

The categorization of answers to the interview questions is presented in table 2. The percentages indicate how many of the participants’ answers matched each category. The differences between the top three categories are small, but the span between the top and the bottom is large enough to justify comparisons.

Problem solving (cateogory A) is the most common concept and it is discussed by more than one third of all participants. It is closely followed by category B that includes concepts related to construction, e.g. building physical objects, and category C including development and improvement.

The impact of engineering on society is also important and this aspect is discussed by 31% of the participants. Related to this is the answer in category E stating that engineering is about being innovative, thinking for the future and contributing with something never done before.

22% of the participants use different academic subjects to describe engineering (e.g. maths, physics) and 13% talk about the intellectual activities con-

Table 1: The most frequently stated engineering terms in the survey. Presented as percentages of all stated terms in the current set.

Engineering term	Mentioned (%)
problem solving	12.5
creativity	5.5
math	4.8
developing	4.1
inventions	3.1
technical	2.8
team work	2.5
research	2.3
hard work	2.2
interesting	2.0
fun	2.0
analysis	1.9
calculation	1.9
constructing	1.6
important	1.5
leadership	1.4
project work	1.3
science	1.3
computers	1.2
thinking	1.1
physics	1.1
designing	1.1
high salary	1.0
challenging	1.0
(other)	38.8

nected to engineering. Teamwork is the least frequent category. Only 9% of the participants discuss teamwork in connection with engineering.

6 DISCUSSION

The results from the survey and the interviews gives us two ways of pinpointing students' conceptions of engineering, and these two angles both support and complement each other.

To some extent, the words from the survey and the answers from the interviews paint the same picture. Problem solving stands out as the most important aspect of engineering, being at the top of both lists. It is also possible to find terms from the survey that match each of the other categories from the interview. Categories B and C relate to construction and development. Both of these terms are found in the survey, but not as frequently as in the interviews. On the other hand, innovation and creativity (category E and F) are the second and fifth terms in the survey list, which is much higher than in the interviews. Overall, all of the aspects of engineering covered by the interviews are also present in the survey, even if the relative importance is different.

A categorization, like the one performed on the interview transcripts, of the terms from the survey would be difficult to perform since the survey terms have no context. While the categories from the interviews give us a richer, more cohesive view, the terms from the survey complement this view.

The terms from the survey (table 1) differ in level of detail compared to the categories from the interviews (table 2). The survey data is in general more varied and deals with somewhat different kinds of terms. When explicitly asking for five engineering terms, as in the survey, a broader picture arises including terms, or concepts, denoting how students think of engineering and work in a more personal way. For example, words like *hard work*, *stressful*, *challenging*, *interesting*, and *fun* are used. On the other hand, it seems like the interviewed students tried to give more general answers that were not always connected to their personal experiences.

Another interesting observation is that academic subjects, like *mathematics* and *physics*, do not appear in any of the top positions. Even though mathematics is third in the list of terms from the survey, it represents only five percent of the terms, and the second highest ranked subject, physics, represents only one percent. In the interviews, the category including academic courses is the seventh most frequent category of a total of ten. We believe that this tells us something about the contrast between the subjects that constitute an engineering education and the application of these to engineering problems. According to our results, students value the latter aspect higher.

The results from (Mosborg et al., 2005) on key concepts recognized by advanced engineers, partially supports our findings. Problem formulation, in our study *problem solving*, is ranked high in our study as well as in (Mosborg et al., 2005). Creativity is ranked as neither important nor unimportant in (Mosborg et al., 2005), but in our findings the picture looks somewhat different. Our participants rank creativity rather high, both in the survey and the interviews, which seems to indicate that engineering students connect engineering with creativity to a larger degree than professional engineers.

In (Turns et al., 2000) technical knowledge was ranked higher than concepts like communication, multidisciplinary teams, and global and social issues. Our findings, especially from the interviews, show the same pattern for teamwork (category J). This is the lowest ranked category in the interviews and, although in the top twenty list of terms from the survey, it represents only 2.5% of the terms. At the same time

Table 2: Categorization of answers to interview question 1 and 2, and frequencies of answers.

Category	Description	Typical words used	Percentage
A	solve problems	solve problems	36
B	realizing concrete products	construct, implement, building, realizing, physical things, hands-on	35
C	improving something that already exists	develop, improve, optimize	34
D	social impact of engineering activities	changing society, ease everyday life, impact on human beings	31
E	contributing with something qualitatively new	innovation, new ideas, thinking for the future, something not built before	29
F	being creative and explorative	create, design, discover, explore, put things together	27
G	static knowledge connected to engineering	knowledge, mathematics, technology, natural science, physics	22
H	intellectual activities	thinking, curious, understanding, challenges	13
I	engineering can be a lot of things	complexity, many things	11
J	teamwork	teamwork, working together, collaborate	9

our results for category D, social impact of engineering, show a contrast to (Turns et al., 2000), where in our findings technical knowledge does not stand out as being among the most important aspects. Some of these differences might be attributed to the different educational systems.

The career motivators that (Extraordinary Women Engineers Coalition, 2005) found among high school girls matches several of the most frequent terms from the survey, e.g. *fun*, *important*, and *high salary*. Even though these words are generic, this indicates a great potential for broadening the recruitment to engineering programs. As stated by (Extraordinary Women Engineers Coalition, 2005), one of the problems is that it is hard for high school girls to see that their motivators can be met by choosing engineering.

7 CONCLUSION AND FURTHER WORK

Swedish engineering students see themselves as creative problem solvers. This factis important. Curriculum designers should consider to use the concept of problem solving more when designing curricula. They feel that engineering has both a general and abstract side, as well as a real, physical manifestation.

We believe that we have a good picture of students' conceptions of engineering, but it would be even more interesting to compare this with the views of professional engineers. (Goel and Sharda, 2004) indicates that students and engineers use the same words to describe how to study engineering, but what about the engineering profession? Will the students' views change when they graduate and start working as engineers? With answers to these questions, engineering programs could be adapted to better prepare students for the engineering profession.

(Loui, 2005) concludes that students get their views of engineering professionalism from relatives and friends. It would be interesting to investigate where Swedish students get their conceptions. The Stepping Stones survey data is a rich source that can be analyzed as a step towards an understanding of where Swedish students receive their conceptions. It would also be valuable to see how students are affected by education and to what extent engineering in general is actually discussed in engineering programs. How do the teachers and educational institutions address engineering? Is there a premeditated way of communicating what engineering is, and if so - what does it look like?

The reported results are presented with a low level of detail regarding different engineering disciplines. An interesting thread to follow up is what the conceptions look like in different engineering disciplines. Is there, for instance, a difference between engineering physics and information technology? If so, what does that difference mean in terms of recruitment?

No studies on conceptions of engineering among active engineers have been performed recently in Sweden, and producing one would be a valid contribution to the field. A comparison between the students' engineering conceptions and active engineers' would be useful in order to determine if there is a difference.

Knowledge on students' conceptions of engineering is essential for practitioners in engineering education. By information on students' conceptions, the teaching can approach students at their particular mindset of the engineering field. Program managers with responsibility for design of engineering programs would also benefit using information on students' conceptions of engineering. Courses could be motivated and contextualized in order to connect with the students. Recruitment officers would also have an easier time marketing why people should chose the engineering track.

Another question, regarding the implication of the conceptions, is if there exists a right, or more efficient, way to view engineering in the education? If there is one, how could we adjust educational planning in order to achieve this more efficient view?

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