What is the Word for ”Engineering” in Swedish: Swedish Students Conceptions of their Discipline

Department of Information Technology
Uppsala University
Box 337, SE-751 05 Uppsala, Sweden

Technical report 2007-018
June 2007
ISSN 1404-3203

Table of Contents

What is the Word for “Engineering” in Swedish: Swedish Students’ Conceptions of their Discipline

Robin Adams (1), Sally Fincher (2), Arnold Pears (3), Jürgen Börstler (4), Jonas Boustedt (5), Peter Dalenius (6), Gunilla Eken (7), Tim Heyer (8), Andreas Jacobsson (9), Vanja Lindberg (10), Bengt Molin (11), Jan-Erik Moström (4), Mattias Wiggberg (3)

1. Department of Engineering Education, Purdue University, USA
2. Computing Laboratory, University of Kent, UK
3. Department of Information Technology, Uppsala University, Sweden
4. Department of Computing Science, Umeå University, Sweden
5. Department of Mathematics, Natural, and Computer Science, University of Gävle, Sweden
6. Department of Computer and Information Science, Linköping University, Sweden
7. Department of Computer Science and Electronics, Mälardalen University, Sweden
8. Department of Computer Science, Karlstad University, Sweden
9. Department of Systems and Software Engineering, Blekinge Institute of Technology, Sweden
10. Department of Mathematics and Natural Sciences, Blekinge Institute of Technology, Sweden
11. School of Information and Communication Technology, Royal Institute of Technology (KTH), Sweden

Background

Engineering education in Sweden – as in the rest of the world – is experiencing a decline in student interest. There are concerns about the ways in which students think about engineering education, why they join an academic programme in engineering, and why they persist in their studies. In this context the aims of the Nationellt ämnesdidaktiskt Centrum för Teknikutbildning i Studenternas Sammanhang project (CeTUSS) is to investigate the student experience and to identify and support a continuing network of interested researchers, as well as in building capacity for disciplinary pedagogic investigation.

The *Stepping Stones* project brings together these interests in a multi-researcher, multi-institutional study that investigates how students and academic staff perceive engineering in Sweden and in Swedish education. The first results of that project are reported here. As this study is situated uniquely in Swedish education, it 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 instantiated in the USA and Australia (Fincher & Tenenberg, 2006).

Literature

Our study draws on several themes in the literature on engineering education, and from several methodological traditions.

Investigating conceptions of engineering may provide insights into why people enter, leave, and remain in engineering. One American study found that high school girls and pre-university educators perceive that engineering is a man's profession and that engineering is a challenging career path that stresses the importance of superior math and science abilities (EWEC, 2005). In this study, high school girls do not perceive the relevance or rewards of being an engineer. In particular, they do not believe that an engineering lifestyle might align with personal and career motivations (e.g., a rewarding and enjoyable job, a good working environment, making a difference, making a good salary, and being flexible). Although the girls in the EWEC study enrolled in science and mathematics courses at the same rate as boys, only 10% reported an interest in becoming an engineer.

Others have investigated how science, technology, engineering and mathematics students experience their university education and how their experiences relate to their persistence in these fields. For example, Seymour and Hewitt (1997) conducted 335 ethnographic interviews across seven institutions and found that American students who persist in science, engineering, and mathematics were not significantly different from those who leave these fields in terms of indicators such as high school and university grades. Rather, the authors found that issues relating to classroom instruction, departmental culture, and interactions with peers and faculty were pivotal in students' decisions to persist in engineering. Other studies suggest that self-confidence and self-efficacy may play a role in persistence in engineering programs, particularly for women (e.g., Besterfield-Sacre et al., 1998, 2001; Hutchinson et al., 2006).

Additional studies highlight disconnections between engineering practice and engineering education worthy of deeper investigation. Dahlgren and Pramling (1985) found that practicing engineers perceive that their work underutilizes the broad knowledge gained in academic settings. Practicing engineers describe "real" engineering problems as emphasizing a move from technical problem solving towards addressing social and environmental contexts. Similarly, Lethbridge (2000) found significant differences when investigating which concepts software engineers perceived as most and least important with respect to practice and how these related to their university education. Jonassen et al. (2006) developed a research based framework for indexing qualities of workplace engineering problems. A sampling of characteristics includes: incomplete information and unanticipated problems, aggregates of well-structured problems embedded in ill-structured problems, multiple and conflicting goals, success of solutions rarely measured by engineering standards but by non-engineering standards, and the need for collaborative problem solving.

Another study sought to uncover the "accidental competencies" that engineering students learn in college (often from other subjects, or from a general academic approach, rather than specific disciplinary skills). These accidental competencies appear to transfer to practice in unexpected ways (Walther & Radcliffe, 2006). Some educators encourage explicitly including these kinds of accidental competencies into an undergraduate engineering curriculum (Berggren et. al., 2003). There are also apparent disconnections between what practicing engineers find rewarding and perceptions of how to be successful in engineering. For example, in one large scale study it was found that what practicing engineers find rewarding about being an engineer is often not emphasized when they are asked what advice is important for successfully pursuing an engineering career (EWEC, 2005). Practicing engineers find involvement on a project from start to finish, having an impact, and interesting and diverse problems that often involve creative thinking as rewarding; their advice for success focuses on excelling in both mathematics and science, and that engineering is challenging but worth the effort.

Curriculum development draws upon, and is often shaped by, conceptions of professional practice. It is also informed by understanding students' conceptions and misconceptions within that domain and efforts to promote conceptual change (e.g., Posner et al., 1982, Sinatra & Pintrich, 2003). As such, it is important to characterize beliefs and values regarding engineering in order to identify appropriate targets of instruction and learning assessments. Much of the existing work on conceptions of engineering has focused on pre-college education. With this age group, a common approach has been to use the "Draw-an-Engineer" task (DAET) (Knight & Cunningham, 2004). This instrument builds from theory on the extensive use of drawing (e.g., "Draw-a-Scientist" task or DAST) by children to capture understandings and perceptions of fields that are otherwise difficult to elicit (e.g., Cunningham, Lachappelle & Lindgren-Streicher, 2005; Thompson & Lyons, 2005). The DAST was originally developed by Chambers (1983) as an open-ended test to investigate children's perceptions of scientists. DAET studies illustrate that pre-college students' perceptions of engineering emphasize images of physical construction over mental aspects of engineering such as modelling and design thinking (Cunningham, Lachappelle & Lindgren-Streicher, 2005). These kinds of studies may also help understand motivations towards pursuing an engineering education.

There is a small but growing body of literature on college students' understanding of engineering and engineering practice. For example, ethnographic investigations into college students' perceptions of engineering reveal the predominance of technical knowledge and mathematical problem solving which may be related to students' limited experience with formulating and defining complex and ambiguous problems (Downey & Lucena, 1997). Turns et al. (2000a) used a word association task to study graduating civil engineering students' schemas of civil engineering and found that technical knowledge predominated significantly over such issues as communication, multidisciplinary teams, and global and societal context issues. Downey and Lucena (2003) also examined how students involved in design experiences perceive the distinction between science and design. Their findings suggest that students perceive design as a lesser subset of the engineering method of mathematical problem solving, and as such are ill prepared for dealing with the ambiguities and subjectivity inherent in engineering design problems. Similarly, Newstetter and McCracken (2001) found that freshmen engineering undergraduates' early conceptions of design tend to conceptualize design as an artistic, creative process – "a blaze of creative light that strikes some and not others" (pg. 70). In a related study, Mosborg et al. (2005) found that advanced practicing engineers ranked as most important among a list of 23 design activities "problem formulation" and "communication". "Building" was ranked among the least important activities and "creativity" was included in neither the highest or lowest rankings.

Our study drew on this work in formulation of our focal research questions. Many of these questions evolved as we delved deeper into the dataset. These changes are documented in the individual studies in the Results Section.

Focal Questions

- How do students and academic staff perceive engineering in Sweden and in Swedish education?
- What are conceptions of engineering in Sweden?
- How is Swedish engineering education "constructed"?
- What do Swedish students perceive they are learning about engineering?
- What does the collection of studies suggest about preparation for engineering professional practice in Sweden?

These questions allow investigation along a variety of subsidiary questions such as:

- Are there differences between first-year and final-year student conceptions of "engineering"?
- Are student conceptions different to those of academic staff?
- Are conceptions of those within education different to those of practicing engineers?
- Are there gender differences?
- Are there differences between different sub-disciplines of engineering (mechanical engineering, civil engineering, software engineering, etc.)?

Research Design

Our research was guided by five central design decisions. Firstly, we did not want to impose an existing framework regarding conceptions of engineering. By using elicitation techniques such as interviews and concept map tasks to draw out a participant's underlying mental structures or models of engineering concepts, we sought to allow important aspects of the experience of engineering education to emerge from our data. Secondly, we wanted the study to be domain independent so that comparisons could be made across engineering domains. This was done by using general "engineering" terms in our study instruments rather than terms that are specific to a sub-discipline (e.g., mechanical engineering or software engineering). Given the complexity behind our research questions we wanted to enable triangulation opportunities to contradict or corroborate findings within the study. This was achieved by combining different approaches and collecting both qualitative and quantitative data. At the same time we wanted to leverage the power of existing instruments that have been validated and replicated. Finally, we wanted the study to be of sufficient scale to allow generalisation. This was achieved by using techniques such as web-based surveys that allow data collection from many participants at several institutions. Therefore, this study comprises four tasks: a web-based survey, the construction of a concept map, a critical incident interview and a photo elicitation interview.

The *web-based survey* is an adaptation of a comprehensive and validated survey of students' perceptions of engineering developed for use in the United States (Eris et al., 2005; 2007). The survey includes both open-ended and closed-ended questions regarding the participant's background, interest and motivation to pursue engineering, self-confidence in engineering skills, knowledge of engineering, perception of their university experience, and academic engagement. For the *concept map task*, participants were asked to construct a concept map from a list of engineering terms (see Turns et al., 2000b) modified with reference to trends in Swedish engineering education needs (Maury, 2004). For the *critical incident interview,* participants were asked to recall a particular experience from their past which encapsulates their concept of "real engineering". For the *photo elicitation interview* participants were shown three images and asked what associations they have for each of them with respect to "engineering".

All data was collected following guidelines regarding the use of human subjects in educational research. In particular, voluntary consent was sought from all participants, and all data was collected and presented in a manner that would protect the privacy of study participants. In the sections below we provide details regarding each study task.

Web-based survey

The web-based survey was adapted from the Academic Pathway Study (APS) survey (Eris et al., 2005). It has been analyzed for construct validity, used multiple times in multiple contexts, and used as part of a longitudinal study where the survey was completed several times by the same set of participants. The goal of this survey is to provide data on skill, identity, and education factors that may influence persistence in engineering. In this study, we administered the survey once but with a large number of participants over several institutions. As such, the survey provides baseline information for a rich set of national data. The use of the survey for this study might also enable opportunities for Sweden and US comparisons.

Survey questions were either preserved unchanged or modified from the original to be appropriate in the Swedish context. Some words were changed to Swedish equivalents to retain the meaning of the item and resolve confusion over the English terms. For example, when asked to rate their satisfaction with their current university on aspects of campus life, the original item of "Quality of instruction of lecturing staff" was replaced with "Quality of instruction by lecturing staff (lärare)". Similarly, the question "Do you have close friends who are practicing engineers?" was replaced by "Do you have close friends who are working engineering?" to resolve cultural differences around the meaning of "practicing engineers". Background questions that had no relevancy for the Swedish context (e.g., questions about pursuing a "double major") were dropped. Some background questions were added to describe issues unique to the Swedish context. For example, the question "What kinds of programs are you taking?" was added to distinguish students from 3, 4, 4.5 and 5 year programs. All modifications were identified and tested by piloting the survey with participants and facilitators of the Stepping Stones project and are described in detail in Appendix B.

Concept map

Concept maps are representational tools for displaying organized, associative networks of knowledge (i.e., semantic networks and knowledge maps). The terms used in concept map activities may be generated by the participant or externally provided. Representations generally include concepts (words enclosed in boxes or circles), links between concepts (lines or arrows) and their semantic relationships (words on the lines) (Novak, 1998). Concept maps often represent hierarchical relationships with the most inclusive concepts at the top of the map and the less inclusive concepts at the bottom of the map. Concept maps have been used as learning, research, and evaluation tools in engineering (see Turns et al., 2000b). They have also been found to be effective in identifying valid and invalid ideas held by science students (e.g., Edwards & Fraser, 1983). An unusual aspect of the creation of concept maps for this study was capturing the maps as *explanograms*.

An "explanogram" captures a drawing as it is being made and allows a user to replay the process of construction at a later time (Pears & Erickson, 2003; Pears et al., 2003). An explanogram is made through the combination of a specific piece of hardware (in effect, a rather fat pen) with which you draw, and a software application which captures the order of the strokes. These are then uploaded to a web-based repository site and the drawing can be re-played as often as required. The explanogram technology allows the synchronised capture of audio, but we did not use this feature in this study.

By using the explanogram technology to capture concept maps we added a new dimension to our analysis, namely that of time. Not only is it possible to see the finished products (i.e. the paper-based maps themselves), but via the explanogram representation, we are privy to the order in which concepts were placed on the paper. This allows us to see the sequence in which the maps were drawn and, on a smaller scale, to discriminate concept clusters by identifying which word was placed first and those which were added later, augmenting and enriching the concept.

Interviews

Interviews are useful techniques for eliciting direct evidence from participants on how they experience a phenomenon (for example, a course, a concept such as "engineering", or a work related experience). This study used two varieties of semi-structured interview techniques, *critical incident* and *photo elicitation*. The critical incident and photo elicitation interviews were carried out in a single session. Semi-structured interviews generally start with a set of specific questions followed by opportunities for the researcher to probe or follow-up on responses from the participants.

Critical incident Interview

A "critical incident" interview begins with the participant recalling a specific experience from their past and proceeds with a variety of interview probes to delve deeper into the situational factors regarding this experience and its meaning for the participant. Critical incident interviews have been used to investigate matters as diverse as work safety (Flanagan, 1954) and naturalistic decision-making e.g. (Klein et al., 1989; Klein 1999).

Photo elicitation interview

A "photo elicitation" interview is based on the idea of inserting a photograph (either generated by the subject or by the investigator) into a research interview. Harper (2002) notes that photos prod latent memory sharpen memory and reduce areas of misunderstanding. They also respond to how people think visually, elicit longer and more comprehensive accounts than interviews, elicit values and beliefs, and connect to core definitions of the self to society, culture, and history. Photo elicitation has a long history either as its own form of inquiry or as embedded broadly within ethnographic work (Becker, 1974; Prosser, 1998). Photo elicitation has been used as a central technique for studies that focus on social class and organization, community and historical ethnography, identity, and culture (including interpretations of "work"). Three photos were used in the interview: one that captured a historical view of engineering, one that represented a low technology context in a real setting, and one that included software controlled components.

Details of the development of these instruments can be found in Appendix D.

Data Demographics

Data was gathered over the academic year 2006/07 from ten Swedish institutions (although not all institutions gathered all forms of data). For the concept map task and interviews, data were given a unique identifier of the form: AF01 where the first letter represents a unique institution code, the second letter represent experience level, of the form F (First Year Student 01), G (Graduating student), A (Alumni) or E (Educator) and the number represents a unique participant. See Appendix H for institutional characterizations. Participants may have contributed to all parts of the study, to just the survey or the just the concept map task and interviews.

Table 1. Distribution and types of data.

Site	Surveys	Concept Maps	Interviews	Interview Types and Totals				Concept Maps Types and Totals			
				F	G	A	E	F	G	A	E
B	60	14	14	6	5		3	6	5		3
C	121	22	22	9	10	1	4	7	10	1	4
D	50	13	13	5	6		2	5	6		2
E	26	10	10	4	4		2	4	4		2
F	83	12	12	5	5		2	5	5		2
K	9	7	7	4	2		1	4	2		1
H	99	24	24	9	11		4	9	11		4
I	52	13	13	6	5		2	6	5		2
Other	21	0	0								
	521	115	115	46	48	1	20	46	48	1	20

Note that data may have been gathered across more than one program within an institution. Concept map debrief data was also gathered, and matches the demographics for concept maps, except for participants HG01, KF02 and KF04 from whom debriefs were not collected. Interviews from institution E were not included in this analysis.

Table 1 shows the total numbers and distribution of the data, where the first column indicates institution. Institution codes were not assigned to institutions who only contributed survey data (see "Other" in Table 1).

Preliminary Results

In this section we describe our general approach to the analysis for each study instrument (survey, concept map, and interviews). We then provide preliminary results for a set of five component studies as described in Table 3 (Study E is last so that it can build off the other studies). As shown here, some studies focus on a single data source, while others cut across data sources. Similarly, the unit of analysis is different for each study – some focus on institutional level characteristics, some on participant level characteristics, and some focus on both institutional and participant level characteristics. Each study was collaboration among a subset of the paper authors. As such, when studies are described, "we" refers to the set of authors involved with that particular study.

Table 2. Compilation of studies across describing data source and unit of analysis.

Study	Unit of Analysis	Data Source			
		Survey	Concept Map	Critical Incident Interview	Photo Elicitation Interview
Study A	Institution Discipline	Subset of constructs			
Study B	Participant (experience, gender)		Map & Explanogram		
Study C	Participant (experience, gender)	Subset of questions		Subset of questions	Subset of questions
Study D	Participant (experience, gender)				Subset of questions
Study E	Participant (gender)	Subset of questions	Debrief		

Participants were recruited to a web-based survey which output data to a MySQL database. Analysis of the survey was based on the set of Academic Pathway Study validated constructs (see Eris et al., 2007) and involved appropriate statistical techniques. Cronbach alphas were assessed to examine construct validity of the survey items for the Swedish context. The set of constructs are identified in Table 3 below, and the mapping to the Swedish version of the survey is provided in Appendix F. The complete internal validity analysis is provided in Appendix G. Most Cronbach alphas were .60 or higher, which is considered an acceptable level of internal consistency.

These constructs have been used to analyze influences regarding persistence in engineering. For example, recent findings (Eris et al., 2007) from the survey suggest no overall difference between students (in their first or second year) who persist in engineering and those ("non-persistors") who do not regard financial motivation or social relevance as a motivation to pursue engineering, perception of the importance of math and science, confidence in interpersonal and professional skills, and reported familiarity with the field of engineering. However, "non-persistors" are more likely to have a higher degree of family influence and a lower degree of a mentor's influence as part of their motivation to pursue engineering. They are also more likely to have lower confidence in their mathematics and science skills, a lower rating of the importance of interpersonal and professional skills, and are more academically disengaged in both engineering and liberal arts classes.

Table 3. Persistence in Engineering Constructs (reproduced from Eris et al., 2007)

CONSTRUCT	DESCRIPTION

1a	Academic persistence
1b	Professional persistence
2a	Motivation (financial)
2b	Motivation (family influence)
2c	Motivation (social good)
2d	Motivation (high school teacher/mentor influence)
2e	Motivation (mentor influence)
3a	Confidence in math and science skills
3b	Confidence in professional and interpersonal skills
3c	Confidence in solving open-ended problems
4a	Perceived importance of math and science skills
4b	Perceived importance of professional and interpersonal skills
5	Knowledge of the engineering profession.
6a	Exposure to project-based learning methods (individual projects)
6b	Exposure to project-based learning methods (team projects)
7	Collaborative work style
8	Extra-curricular fulfillment
9	Curriculum overload
10	Financial difficulties
11a	Academic disengagement (liberal arts courses)
11b	Academic disengagement (engineering related)
11c	Academic disengagement (overall)
12	Frequency of interaction with instructors
13a	Satisfaction with instructors
13b	Satisfaction with academic facilities
13c	Overall satisfaction with collegiate experience

The concept map task for this study was modified from an existing task (see Turns et al., 2000b). The original task included 18 terms characterizing the goals of engineering education as represented in accreditation policies. The original terms included: research, science, experimentation, engineering, uncertainty, theory, society, evaluation, modeling, ethics, economics, impact, design, environment, implementation, teamwork, communication, and analysis. To align with current issues in Swedish higher education, terms were modified and appended based on an analysis of recent documents regarding the nature of Swedish engineering education (Maury, 2004). For example, the term “uncertainty” replaced the term “complexity”. Similarly, the following terms were added: sustainable, innovation, judgment, multidisciplinary, mathematics, and technology.

Participants were recruited for the concept map task during the 2006-07 academic year (see Appendix C for protocol and instrument). Administration of the concept map task involved a warm-up activity to familiarize the participant with the process of creating a concept map and in the use of the explanogram pen. The warm-up task was designed to have no single correct answer, to minimize anxiety, and maximize the potential that the map constructed illustrates the participants’ point of view. Background information was also collected regarding participant’s age, gender, program they were enrolled in (e.g., 3 year, 4 year, etc.), highest degree obtained and when they received it (if appropriate). Finally, participants were completed a debrief (see Appendix C) which asked how the terms in the map related to their experience in and out of university classes as well as general comments on the ease or difficulty of the task.

Traditionally, analysis of concept maps focuses on the content and structure of the map such as (1) the number of links, (2) the number of cross links, (3) the number of hierarchy levels, and (4) how concepts are grouped (Turns et al., 2000b). Our use of explanograms allows investigating the process by which the maps are created, for example the placement of terms over time.

Interview analysis

Participants were recruited for the critical incident interview and photo elicitation interview during the 2006/07 academic year (see Appendix D for protocol and instrument, Appendix E for images used in the photo elicitation interview). Critical incident interviews were generally administered first. This was done so that reflections from the photo elicitation interview did not influence responses to the critical incident probes. Situations in which the sequencing of interviews was different are identified in the analyses. All interviews were digitally audiotaped and transcribed.

The analysis of interview data can take many forms. However, a central idea is that the themes emerge from the data rather than a pre-determined analysis scheme. Analysis may include extracting common constructions from experience ("engineering" may be a matter of scale), grouping by similar critical incidents (they may involve the participant in building something), or by type (they may involve hitting obstacles in a process) (Ryan & Bernhard, 2003).

Preliminary Analyses: Studies A – E

The sections below summarize the preliminary work for Studies A-E (see Table 2). Each study draws on the results and analysis techniques described above (e.g., survey, concept map, interviews).

Study A: A Comparative Analysis of the Survey Data

To conduct a comparative analysis using the survey data, two main activities were performed: comparisons by institution (data collection site) as organized by the constructs (see Table 3, Appendix F and G) and preparation for comparisons by discipline. All analyses were conducted using the R software suite for statistical computing (see Appendix G).

Comparisons by institution of construct data

In this part of the data analysis, the targeted constructs (see Appendix G) of the survey data were compiled, plotted and analyzed per institution to explore students' perceptions about engineering education at their respective university. As an overall observation, it is fair to say that the results from this part of the data analysis were not all that interesting. In other words, there were few instances of noticeable differences across the institutions. With the exception of Construct 12 ("Frequency of interaction with instructors") (see Figure 1), there are few constructs where there is an observable difference between the universities surveyed. This can also be seen in the graphs for Constructs 11c, 13a and 13b (Figures 2, 3, and 4 respectively). Therefore, it seems that institution is not an interesting unit of analysis. Instead, it suggests that this data, or the constructs thereof, may be more usefully analyzed with respect to factors such as gender and disciplinary program.

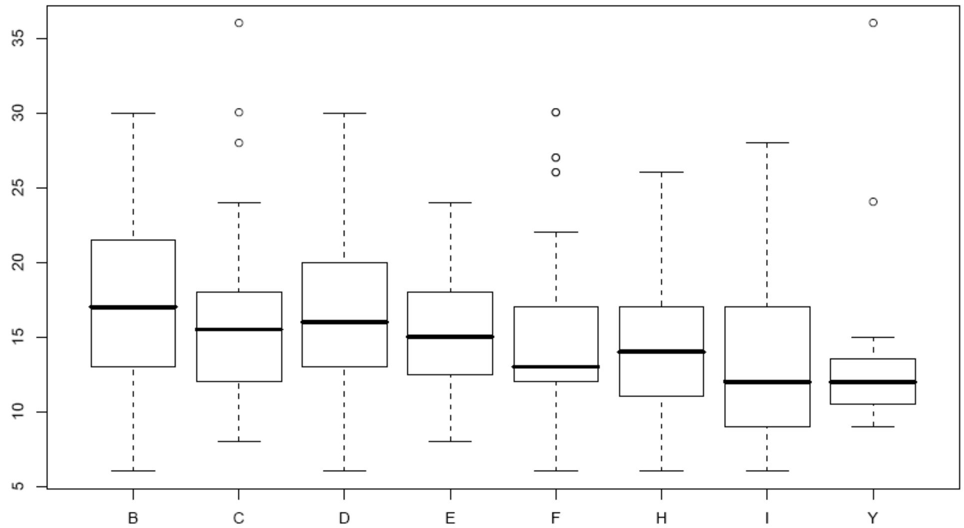


Figure 1. Box plot analysis for Construct 12 (frequency of interaction with instructors) across all institutions. The x-axis refers to the institution (e.g., B) and the y-axis refers to the frequency of responses for that construct.

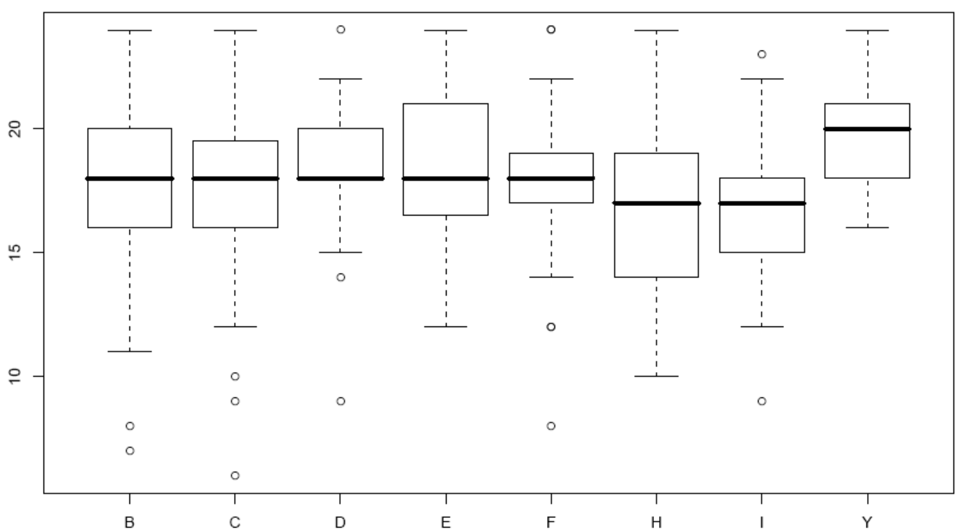


Figure 2. Box plot analysis for Construct 13a (satisfaction with instructors) across all institutions. The x-axis refers to the institution (e.g., B) and the y-axis refers to the frequency of responses for that construct.

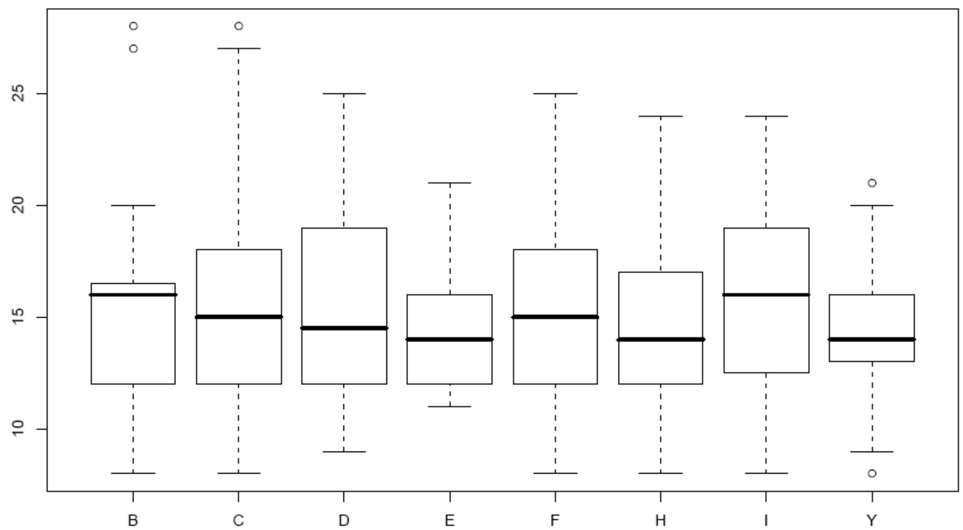


Figure 3. Box plot analysis for Construct 111c (academic disengagement overall) across all institutions. The x-axis refers to the institution (e.g., B) and the y-axis refers to the frequency of responses for that construct.

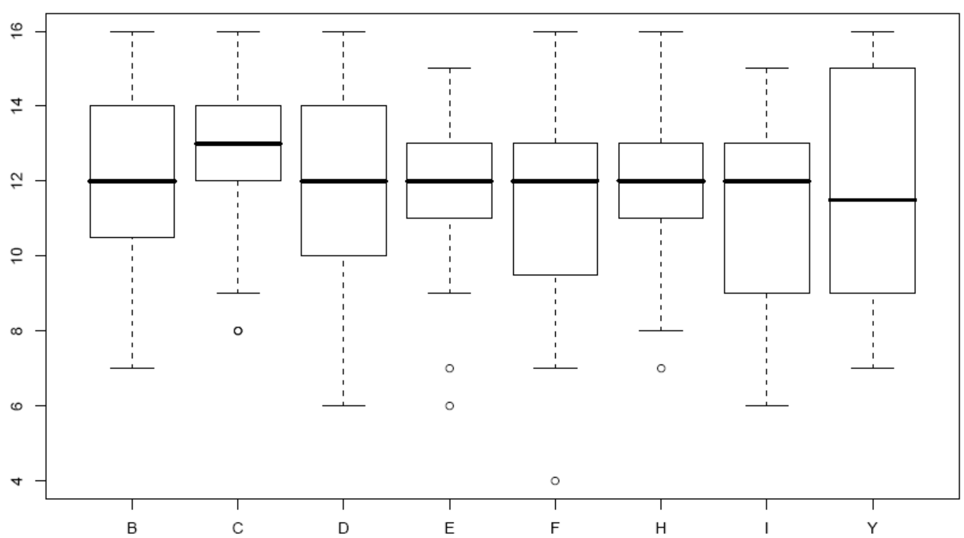


Figure 4. Box plot analysis for Construct 13b (satisfaction with academic facilities) across all institutions. The x-axis refers to the institution (e.g., B) and the y-axis refers to the frequency of responses for that construct.

This analysis suggests considerable consistency in what Swedish engineering students think about engineering education at their universities. In this respect there appear to be no significant differences among the subjects of the survey sample for most of the constructs. The only case, Construct 12, which characterizes the frequency of interaction between students and instructors, is hardly surprising due to such institutionally variable factors such as the availability of resources, pedagogical approach, and the number of students.

Preparation for comparisons by discipline of construct data

To facilitate subsequent analyses, we identified a set of categories of engineering education disciplines based on the educational programs that occur in the survey sample. We propose that this should be consistently applied in all areas of the data where educational programs manifest themselves.

We grouped all engineering education programs that are found in the data into a set of categories (see also Appendix I). The classification is a reflection of the education programs in which the students are enrolled and should consequently not be considered as a categorization of Swedish engineering education as a whole. These categories are identified in Figure 5.

Preliminary categories for engineering education disciplines	
1. Aerospace eng. 2. Bio-inspired and agricultural eng. 3. Biomedical engineering 4. Chemical eng. (and chemistry) 5. Civil eng. (*Swe.* väg och vatten) 6. Computer eng. 7. Computer Science 8. Electrical eng. (and micro-electronics) 9. Geological eng. 10. Information technology 11. Materials science and eng.	12. Mathematics 13. Mechanical eng. 14. Interaction design 15. Software eng. 16. Physics (and technical physics) 17. Systems in technology and society 18. Energy eng. 19. Industrial economics 20. Construction eng. 21. Other (less than 5 respondents in total) a. "Other" (from the survey data compilation) b. Cognitive science c. Transport and logistics

Figure 5. Preliminary categories for engineering education disciplines as represented in the survey sample.

Based on this classification, it should be possible to further consolidate the amount of categories by creating groups which contains few students (e.g., categories numbered 1, 9, and 11). In that way, it may be possible to observe interesting differences among the various sub-disciplines of engineering education.

Study B: Student's views on concepts related to engineering as represented in the concept map

Engineering can be a hard concept to define. We are interested in how people involved in engineering education experience various aspects connected to engineering. We collected data from engineering students during the first and last years of their education and from engineering education educators. We gathered information from the participants using three different methods that allow triangulation across different forms of evidence: a web based questionnaire, the drawing of a concept map (CM) using explanogram technology and an interview that was divided into two parts; a critical incident interview and a photo elicitation interview.

Our primary goal in the concept map analysis has been to explore the data, trying to find interesting patterns that could be further analyzed. A secondary goal has been to explore various ways of analyzing concept maps. Our overarching research question is: *What can we learn about students' and educators' views of engineering from their Concept Maps (CMs); how do they relate engineering to other concepts and which seem to be the most and least important concepts in their CMs?* To operationalize this question we developed a set of more specific questions:

- Which are the most or least important concepts in the drawings?
- Can the structure or appearance of the drawings be categorized in some way?
- Are particular concepts "closer" to engineering than others?
- Are there any differences for different groups of subjects?

We used two general approaches to analyze the concept maps (CMs); visual inspection and objective measurement (e.g. counting something). Using these two approaches we focused on characterizing the structure of the maps, the distance between concepts in the map, and the sequence of placing concepts in the map. In some cases we analyzed comparisons across gender and experience level. Preliminary results from these analyses are provided in the sections below.

Central concepts

We analyzed which concepts were central in the drawings. We defined "central" by the following properties: central in a spatial sense (in the "middle"), on the top of the drawing serving as a header, or having many links, or drawn as frame that includes other concepts, or finally as explained by additional text. Several concepts can simultaneously be considered as central. Which of the concepts appeared as central most often or rarely? To find the central concepts three researchers visually inspected all CMs and categorized them until they reached full agreement. All CMs with engineering as one of the central concepts were sorted out in a first pass. We then inspected the remaining CMs a second time and noted down all central concepts. One CM did not have any concept that could be interpreted as central; it was drawn as a sequence of concepts in a single line.

Table 4. The most frequent central concepts in the Concept Maps.

Central concept	Frequency count
Engineering	86
Science	11
Society	7
Research	6
Design	4
Technology	4
Economics	3
Environment	3
Implementation	3
Innovation	3
Modelling	3
Multidisciplinary	3
Theory	3
Analysis	2

In total, 86 (75%) of the drawings placed engineering as a central concept. The other 29 (25%) drawings were analyzed to discover their central concepts, identified in

Table 4. We took a liberal approach and allowed more than one central concept in a drawing in this analysis. The 86 maps with "engineering" as a central concept were not further analyzed for additional central concepts.

There were no differences regarding the use of engineering as central concept between first year students (71.7%) and last year students (72.9%). Educators used engineering as the central concept to a higher degree (85.7%).

Structural characterization of concept maps

To categorize the overall structure of the CMs, we spread them on the floor to get an overall impression of typical and atypical patterns. Since hierarchical maps, network-like maps and groupings were quite frequent we decided to group the CMs into those categories, plus a fourth category for all others. We then inspected the CMs together, in several passes, until we reached agreement, defining new categories when needed.

A tentative classification scheme involved 4 categories: hierarchies (37%), networks (30%), groups (14%) and those CMs that did not fit any of these categories (19%). Examples of these are provided in Figure 6. As a note, those that did not fit any categories were tentatively classified as "meta" (4%), mixed1 (groups and hierarchies combined in some way) (3%), mixed2 (groups, hierarchies and networks combined in some way) (3%), two-layered (CMs with two different layers of information, e.g., circles around groups in addition to arrows) (3%), unclassified (CMs with an obvious structure that did not fit any of our categories) (3%) and CMs without any detectable structure (1%).

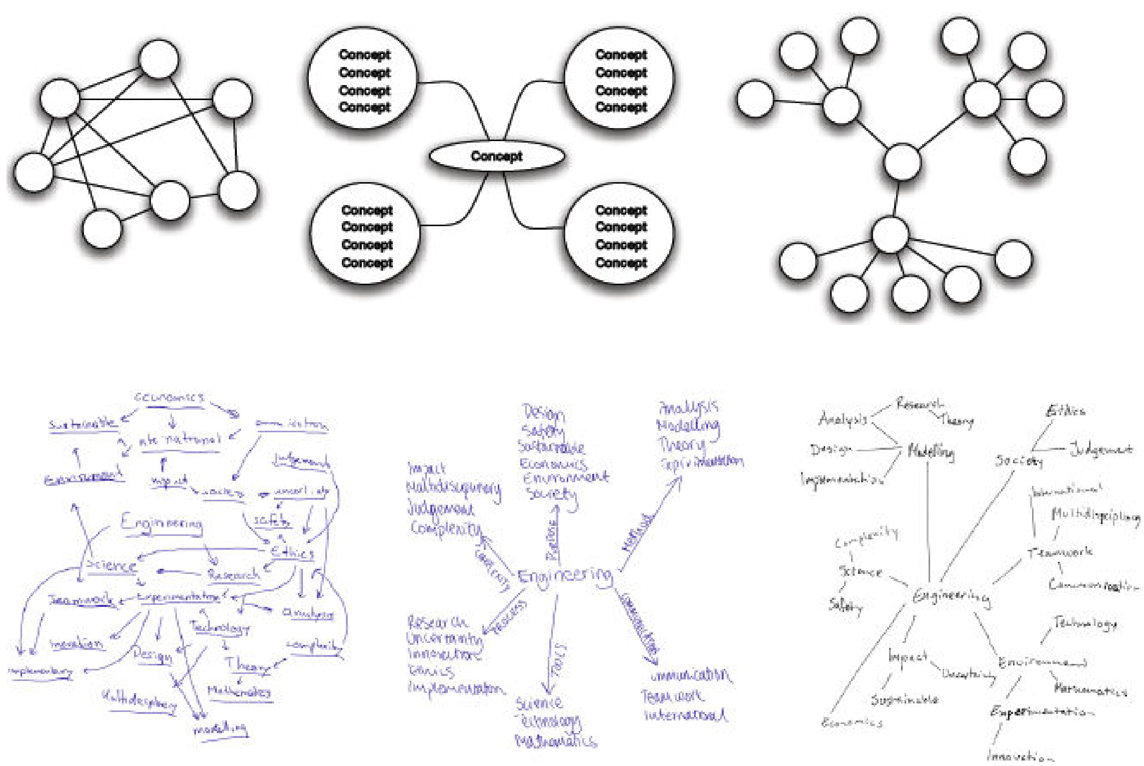


Figure 6. Schematic examples (top) and actual examples (bottom) for CMs classified as network, group and hierarchy (from left to right).

The three categories of participants (first year students, last year students and educators) are evenly distributed over this categorization of the concept maps. We can therefore conclude that either our way of classification was not suitable, or that years of education do not have an impact on how participants chose to represent their ideas about "engineering". However, we have noticed a difference in style with respect to gender. This analysis is provided in a later section.

Rich and lean CMs

In another classification approach, one researcher classified about a third of all CMs into "rich" versus "lean" descriptions. As rich, we considered those CMs, which had (a) all concepts connected in some way (i.e. no "islands") and (b) were annotated in some way (usually by naming the relationships).

Our analysis showed that males and educators draw rich CMs much more often than female students. There was no difference between first year and graduating students (see Table 5).

Table 5. Distribution of rich CMs divided by group.

Group	Frequency in %
All participants	37
All Females	29
All Males	38
Female students	15
Male students	36
First year students	32
Graduating students	33
Educators	55

Additional analyses were undertaken such as the timing of when certain concepts were placed on the map. For this analysis, the term "analysis" was special in the sense that it was one of the first terms in the list provided (see Appendix C). It might be assumed that this word would often be the first drawn. However, the concept "engineering" is far more frequent (58 versus 11). In 9 of these 11 cases where "analysis" was first drawn, the CM was been classified as "lean", which may support the assumption that some participants were careful with how they drew the maps and took their time to annotate and explain what they did, while some others put the concepts in the map, starting with the first concept in the list.

Similarly, the only five CMs that had "communication" as their 2nd concept had also been classified as lean – "communication" was the 2nd concept in the list provided to the participants. Five "lean" CMs had "environment" as the last concept where only one of the "rich" did.

We also noticed a difference with respect to gender and the frequency of drawing styles; 37% of the total population drew hierarchical maps and 30% drew networks. When dividing the maps by gender, we conclude that hierarchies are more frequently used by the females (see Table 6). 35% (34) of the males drew hierarchic maps and

31% (30) of them drew networks. In addition, men tend to create “group” concept maps more frequently than women.

Table 6. The frequencies for the three most used types of Concept Maps, by gender.

Gender	Hierarchies	Networks	Groups
Females	47% (8)	23% (4)	5% (1)
Males	35% (34)	31% (30)	15% (15)
Both	37% (42)	30% (34)	14% (16)

Distances between relations of particular interest

We also developed some quantitative measures. To analyze the “closeness” of concepts to engineering, we used the following definition of distance: concepts in the same group have distance “1” and for concepts with edges between them, we counted the edges on the shortest path between the concepts. Concepts without any relationships between them have not been counted.

The distances from “engineering” to the concepts “society”, “teamwork”, “theory”, “mathematics”, “uncertainty” and “technology” were measured by counting the edges between them. An additional analysis was conducted for the terms “innovation”, “implementation” and “design”.

Early results indicate that “technology” is closest to “engineering” and that “society” is closer than “mathematics”, but more distant than “technology”.

Order of appearance of related concepts

The use of explanograms allows us to analyze the order in which concepts are introduced and how they are placed on the paper. We are currently gathering the information to analyze this and there are indications that words are written in an order that is not obvious by looking at the static result. We conducted three analyses: which words were placed early in the generation of the CM, which words were placed late, and the overall sequencing of concepts placed on the CM. For each of these we compared across gender and experience level.

Words in the beginning

The first word drawn in the CMs was counted and the most frequent words were: engineering (58), analysis (11), science (10), technology (6), research (6) and society (5). The most frequent introducing word pairs were: [engineering, analysis] (11), [engineering, science] (7), [engineering, design] (6), and [engineering, mathematics] (6).

The 17 females in the study used only 7 of the 26 possible concepts as their first printed word on the concept map. Those concepts were engineering (9), research (2), science (2), analysis (1), communication (1), society (1), and teamwork (1). The most common combination of words were [engineering, analysis] (2) and [engineering, science] (2). For the males, the first concept printed was: engineering (49), analysis (10), science (8), technology (6), research (4) and society (4). The most common introducing word pairs were [engineering, analysis] (9), and [engineering, science] (5).

When participants were analyzed separately as first year students, final year students and educators, the trend looks slightly different. First words for first year students: engineering (21), science (4), analysis (3), technology (3) and teamwork (2). First pairs: [engineering, design] (3), [engineering, mathematics] (3) and [engineering, science] (3). In comparison, first words for last year students: engineering (25), science (6), analysis (5), research (4), technology (3); first pairs: [engineering, analysis] (6) and [engineering, science] (3). First words for the educators: engineering (11), analysis (3), society (2); first pairs: [engineering, analysis] (3) and [analysis, design] (2).

Words at the end

It is possible that words put in the very end of the concept map session are the ones that are hardest for the participants to relate to engineering. One reason may be language, that the participants are unfamiliar with certain words. Another reason may be that the participants may have a hard time relating certain words with the rest of the concepts. The following concepts were the ones that the participants put in their CMs last: uncertainty (19), multidisciplinary (17), complexity (10), sustainable (8) and environment (6).

The females follow this trend; although they seem to have more associations with environment than the group in whole. For the women in the study, concepts that were kept until the end were: complexity (4), multidisciplinary (3), uncertainty (2) and sustainable (2). The males also follow the overall trend (they are in majority): uncertainty (17), multidisciplinary (14), complexity (6), sustainable (6) and environment (5).

First year students follow the trend: uncertainty (9), multidisciplinary (6), complexity (5), sustainable (3) and implementation (3). The last year students seem to be familiar with "complexity": multidisciplinary (7), uncertainty (6), environment (4), sustainable (4), safety (3) and international (3). None of the educators left the word "sustainable" to the end of the task. Multidisciplinary (4), uncertainty (4), complexity (3), impact (3) and modelling (2) were the words they most often placed last.

In-depth analysis of order

We also analyzed the order in which the concepts were introduced for a random subset of CMs (25%). Figure 7 shows box and whisker diagrams for each of the 26 given concepts. Participants that used additional concepts are not included in the analysis. Moreover, if a concept was used several times, we only considered its first appearance.

Each row in Figure 7 shows the minimum, first quartile, median, third quartile and maximum position for a specific concept. Some concepts in our sample were consistently introduced early (e.g., engineering and research), whereas some were consistently introduced late (e.g., uncertainty and impact).

We also analyzed differences between groups of participants in this subset for specific concepts. For example, we looked at differences between alumni (A), educators (E), first year students (F) and graduating students (G) regarding when "mathematics" was placed on their CM. The median for both first year and graduating students is around seven whereas it is around 12.5 for educators (see Figure 8). These results corroborate the results of the concept debrief analysis (see Appendix J).

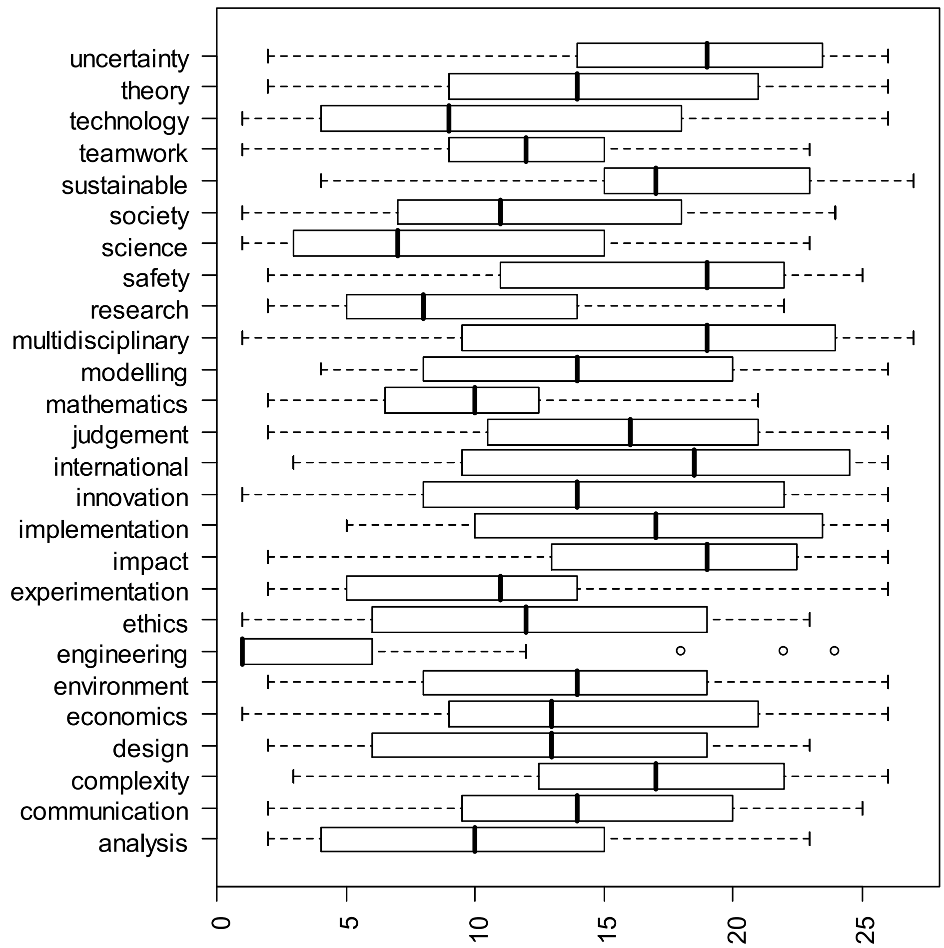


Figure 7. Order of appearance of concepts in CMs.

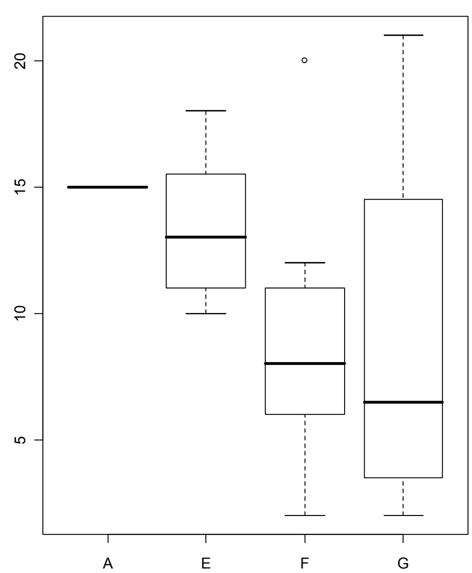


Figure 8. When the concept "mathematics" was introduced into the CMs.

Study C: What do students and educators think are elements of engineering?

One of the focal questions of the Stepping Stones project deals with conceptions of engineering in Sweden. We wanted to know what students and educators think are the elements of engineering.

<u>Method</u>

We focused on three of the interview questions: the first two, Q1 and Q2, and Q5 (described below).

> Q1: In a few words, what would you say real engineering is?
> Q2: Can you give me some examples of engineering in the world
> Q5: After everything we've talked about, what would you say "engineering" is for you?

All responses to these questions were digitally cut from the transcripts and printed out. Keywords and phrases in Q1 were first marked and then grouped into ten different categories by one person (see Table 7). Another person verified the categories. The same process was used for Q5 where we found that the same categories could be used to group responses. The responses to Q2 were also treated in the same way, but since these were mostly nouns that left little room for interpretation only one person coded these. For Q2 we identified 11 different categories (see Table 8).

Table 7: Categorization of responses to Q1 and Q5

Code	Description	Examples
NEW	contributing with something qualitatively new	innovation, new ideas, thinking for the future, something not built before
CRE	being creative and explorative	create, design, discover, explore, put things together
DEV	improving something that already exists	develop, improve, optimize
CON	realizing concrete products	construct, implement, building, realizing, physical things, hands-on
SOLVE	solve problems	solve problems
THINK	intellectual activities	thinking, curious, understanding, challenges
KNOW	static knowledge connected to engineering	knowledge, mathematics, technology, natural science, physics
SOC	social impact of engineering activities	changing society, ease everyday life, impact on human beings
TEAM	teamwork	teamwork, working together, collaborate
COMP	engineering is diverse or complex	complexity, many things

Another source for analyzing participant's conceptions of engineering is available in question 38 in the survey; Q38: In the space provided, list 5 terms you would use to describe "engineering". Based on the responses provided, we cleaned the data, translated some of the answers to English and counted the terms and phrases.

Table 8: Categorization of responses to Q2

Code	Description	Examples
BRIDGE	fairly large and concrete objects	bridges, tunnels, roads, infrastructure, buildings, houses, pyramids, aqueducts, Eiffel tower, Turning Torso, airport in Japan
TRANS	ways of transporting people or goods	cars, trains, buses, airplanes, bikes, boats, vehicles
TOOLS	everyday tools mostly for personal use	TV, mobile phones, coffee machine, digital pen, saxophone, chair, radio equipment, wrench key, DVD player
ENER	energy, natural resources and environment	energy, nuclear power, electricity, cleaning technology
HUM	impacts on basic human life	health care, medical machines, harvesters, food factories
MECH	mechanics, mostly for professional use	mechanical devices, robots
SYS	large abstract systems	systems, networks
SOFT	software	software, computer programs
COMP	computers	computer
SUBJ	different subjects related to engineering	physics, chemistry, mathematics, electronics
ALL	engineering is everywhere	everything, everywhere, a lot

Initial findings

There are two noticeable changes in the way the participants characterize engineering from Q1 to Q5. At the beginning of the interview 17% describe engineering using examples of different academic subjects (e.g. mathematics, physics), but at the end that number decreased to 8%. Also, the proportion that mentioned the impact of engineering on society increased from 12% to 28% during the interview (see Figure 9).

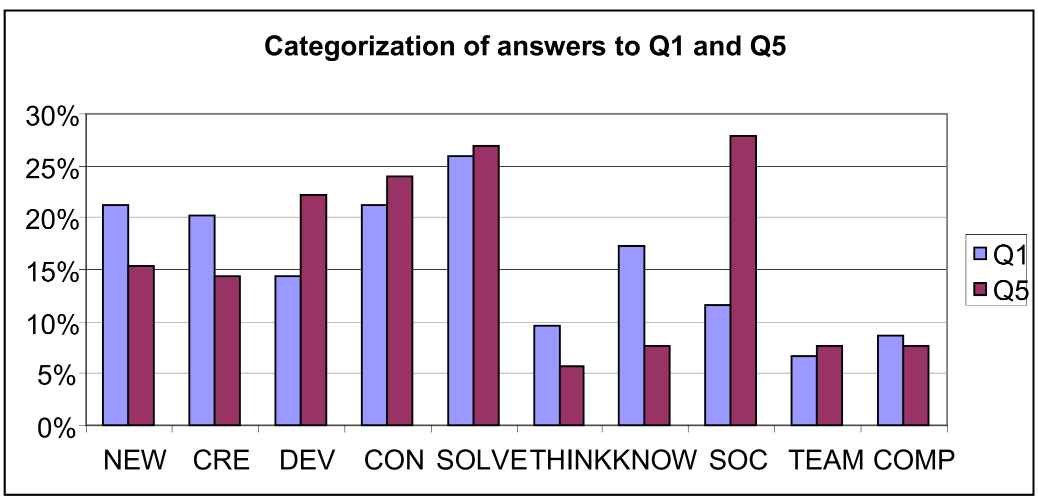


Figure 9: Categorization of answers to Q1 and Q5

Taking the responses in both Q1 and Q5 together there are some differences with respect to gender (see Table 9). 56% of the females characterize engineering in terms of innovations and contributing something new, compared to only 25% of the males. Also, about twice as many females (19% compared to 10%) describe engineering as involving teamwork. There are also differences between first year students and graduating students (see Table 10). Only 2% of the first year students describe engineering as an intellectual activity, compared to 23% of the graduating students. 38% of the first year students mention innovations as a part of engineering, compared to only 20% of the graduating students. Twice as many educators as students think that teamwork is connected to engineering.

Table 9: Responses to Q1 and Q5 by gender

Subgroup	N	NEW	CRE	DEV	CON	SOLVE	THINK	KNOW	SOC	TEAM	COMP
Male	88	25%	23%	27%	39%	33%	14%	25%	30%	10%	20%
Female	16	56%	38%	44%	19%	56%	13%	6%	38%	19%	25%

Table 10: Responses to Q1 and Q5 by first year, graduating students and educators

Subgroup	N	NEW	CRE	DEV	CON	SOLVE	THINK	KNOW	SOC	TEAM	COMP
First year	42	38%	29%	33%	29%	40%	2%	17%	29%	10%	21%
Graduating	44	20%	25%	34%	41%	32%	23%	27%	34%	9%	23%
Educators	18	33%	17%	11%	39%	39%	17%	22%	28%	22%	17%

When it comes to Q2 where the participants were asked to give examples of engineering in the world, the most common answer (62%) is bridges, buildings or other fairly large concrete objects. Transportation counts for 25% and everyday tools and machines (e.g. TV, mobile phone) 24% in total. The results for the everyday tools and machines category are different between the subgroups: 17% for first year students, 25% for graduating and 39% for educators. Educators are also more likely to give examples related to human factors (e.g. food, medicine). This is also the case for gender: 19% of the females give these kinds of examples, compared to 5% of the males (see Tables 11 and 12).

Table 11: Responses to Q2 by first year students, graduating students and educators

Subgroup	N	BRIDGE	TRANS	TOOLS	ENER	HUM	MECH	SYS	SOFT	COMP	SUBJ	ALL
First year	42	69%	24%	17%	5%	7%	2%	0%	17%	21%	0%	21%
Graduating	44	57%	23%	25%	9%	2%	9%	2%	14%	23%	9%	25%
Educator	18	56%	33%	39%	17%	17%	0%	6%	11%	17%	11%	11%

Table 12: Responses to Q2 by gender

Subgroup	N	BRIDGE	TRANS	TOOLS	ENER	HUM	MECH	SYS	SOFT	COMP	SUBJ	ALL
Male	88	63%	27%	24%	8%	5%	2%	2%	16%	20%	6%	22%
Female	16	56%	13%	25%	13%	19%	19%	0%	6%	25%	6%	19%

Matching the responses from Q1 and Q2 we can answer questions like: How many of the participants who describe engineering as X give Y as an example (see Table 13). Of those who describe engineering as an intellectual activity, only 20% use bridges or buildings as examples. This can be compared to the participants who describe engineering in terms of creating or construction. Of these 76% and 77% respectively use bridges and buildings as examples. The difference is even larger when it comes to everyday machines. Only 7% of those who describe engineering as about construction give such examples, compared to 86% of those who answer teamwork on Q1.

Table 13: Q2 (examples of engineering) comparison with Q1 (What is engineering?)

	N	BRIDGE	TRANS	TOOLS	ENER	HUM	MECH	SYS	SOFT	COMP	SUBJ	ALL
NEW	22	68%	23%	18%	14%	14%	5%		14%	14%	5%	27%
CRE	21	76%	29%	29%			5%		19%	10%	5%	19%
DEV	15	40%	33%	7%			7%		13%	13%	13%	40%
CON	22	77%	23%	23%		9%		5%	18%	23%	9%	18%
SOLVE	27	52%	19%	26%	19%	7%	11%	4%	19%	30%	7%	15%
THINK	10	20%	30%	20%	10%		20%		20%		10%	20%
KNOW	18	56%	17%	22%	17%	6%	6%		6%	33%	6%	22%
SOC	12	58%	25%	17%	17%	17%	8%			17%		25%
TEAM	7	57%	43%	86%						29%		
COMP	9	56%	44%	44%	11%				11%	11%		11%

We also split the answers to Q1 and Q5 depending on whether the participants did the concept map or the interview first (see Table 14). There are several differences. For example, of those who did the concept map before the interview 35% mention innovation as an aspect of engineering compared to 19% of those who started with the interview. The opposite is true when it comes to problem solving. 50% of those who did the interview first say that engineering is about problem solving compared to only 31% of the participants who started with the concept maps.

Table 14: Responses to Q1 and Q5 divided by order of tasks

First task	N	NEW	CRE	DEV	CON	SOLVE	THINK	KNOW	SOC	TEAM	COMP
Concept map	72	35%	25%	26%	42%	31%	15%	22%	35%	8%	19%
Interview	32	19%	25%	38%	22%	50%	9%	22%	22%	19%	25%

Study D: Associations with "engineering" from photographs

In this project students and educators were interviewed about their ideas of engineering. The interview was divided into a critical incident interview (where students were asked about an engineering experience they have had), a photo elicitation interview (where participants were asked about the associations of engineering they had with three different images), and a final interview question regarding how the participant's ideas about engineering have changed. The photo elicitation part of the interview was analysed for this subsidiary study.

The total number of interviews studied was 104. All interviews had been transcribed verbatim and those transcripts were used in this study. The data was collected at eight different universities in Sweden between January and May of 2007. The participants in this study were selected among first year and graduating students as well as educators. The distribution among the group is provided in Table 15.

Table 15. Participants differentiated into categories

	Number	Percent
Educators	18	17.3 %
First year students	42	40.4 %
Graduating students	44	42.3 %
Female participants	16	15.4 %
Male participants	88	84.6 %
Total	208	208

The photos were shown one at a time and marked A, B and C (see Appendix D and E). All were shown in this order except for 10 interviews where the photos were shown in a different and random way. In this study this randomization has not been taken into account.

Figure 10. Image A used in the photo elicitation

During the interview the participants were asked “What associations of engineering does image A (B, C) have for you?” at the same time the photo was shown. The part of the interview with the photo elicitation has been extracted and analysed for specific words and concepts. The associations have been classified and entered into a spreadsheet for graphical presentation. At this point only Image A has been analyzed, others will be part of a future study.

For image A the responses have been classified as shown in Table 16.

Table 16. Categories observed in interview related to Image A.

Code	Description
Plan	Planning, analysing, interpretation of results, developing, solving a problem
Male	Male dominance, no females
Team	Team work, group work, solving problem together, communicate with others
Sci	Science, math, physics
Eco	Economics, stock market, economics of a project, statistics
Old	Old fashion engineers, old way of engineering, traditional picture of engineers

Results for Image A

Graphical representations of the classification are shown in Figures 11 and 12. Both diagrams show the same data but divided into different groups of participants.

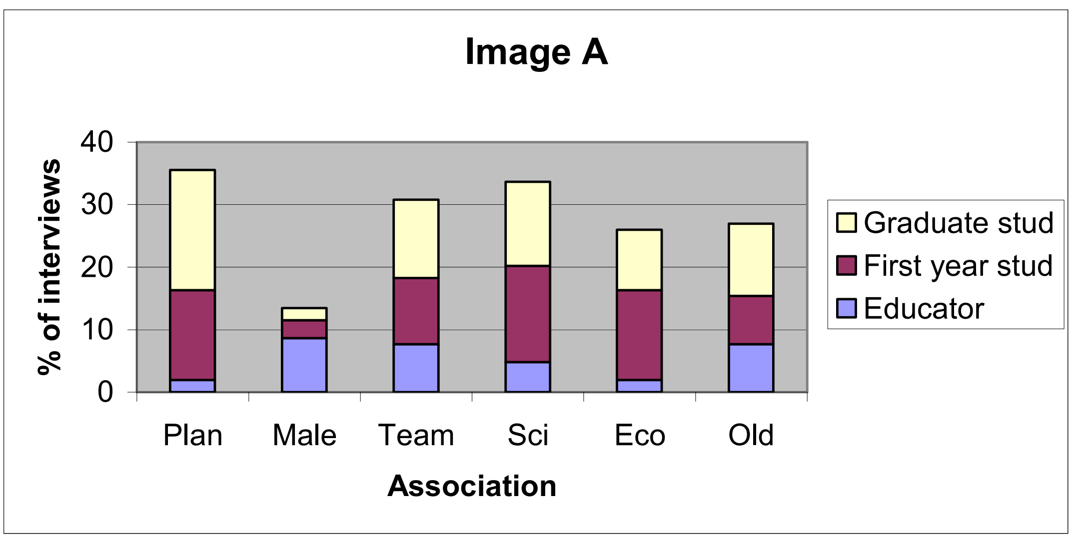


Figure 11. Diagram with classified data divided into groups with first year students, graduating students and educator

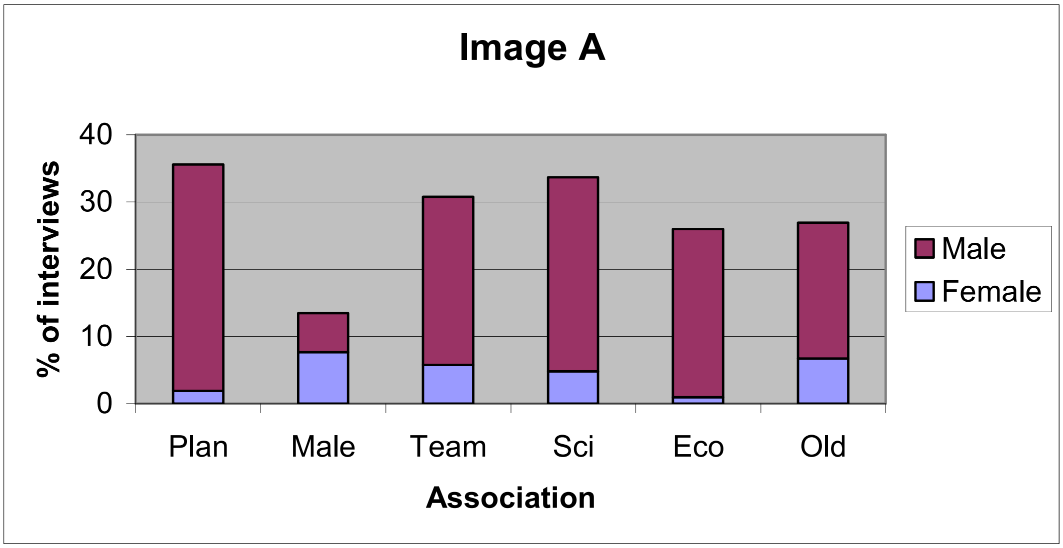


Figure 12. Diagram with classified data divided by gender

The reader should take into account that there are not equal numbers of participants from each category. The results are summarized as follows (by categories from Table 16):

Plan: Participants associate the image to planning a project, analysing something, interpretation of results, developing something new or solving a problem. Graduating students seemed to make this association to a higher extent then first year students; however the difference was not significant. Also 40% of the male participants had this association compared to 13% of the female participants.

Male: Participants that observe and associate that there are only men in this picture are classified into this group. Not surprisingly, female participants made this association to higher degree. It is also worth noting that educators made the same association. 50% of females and 50% of educators did this association compared to 7% amongst all male participants.

Team: Participants that associate teamwork and people working together with this image are classified into this group. The only noticeable difference is that educators are slightly more represented.

Sci: Participants that associate picture A with mathematics, physics or scientific research fell into this group. In this case there is no noticeable difference.

Eco: Participants that associate the image with economics, the stock market, project economy or statistics are classified into this group. First year students and male participants are more represented. 36% of the first year students made this association compared to 23% of graduating students. 30% of male participants made this association compared to 6% of the female participants. Many participants with this association said the picture could equally well represent economists and didn't have anything at all to do with engineering.

Old: Many participants associated this picture with "old ways" of engineering or made some comment that it was old, maybe from the fifties. Graduating students and educators are represented to higher degree in this group. 44% of the educators made this association compared to 19% first year students and 27% graduating students. Also 44% of female participants compared to 24% of male participants made this association.

Female participants and educators in particular associated this picture with male dominance and old ways of engineering. One reaction from one female first year student when she saw this photo is particularly salient: "[Sigh] Dominance male dominance in engineering and this is very traditional for example in my program we only have three girls in forty-five people so I thought of I would change it ..." First year students and male participants tended to point out that this image does not need to be engineers; it could as well be economists.

Study E: A gender point of view

The students participating in our study were asked to answer a total of 48 questions in a survey. The total number of participants was 521, where 108 were females, 383 males and 30 did not state their gender. We questioned whether there was any obvious gender differences in the answers given by the females as compared to the males, and then if differences could also be seen in the concept maps and the results from the interviews and the concept map debriefs. We chose to focus on a few aspects, such as why do students choose to study engineering, how do they rate their own skills as compared to their classmates and what traits do they believe are important for a working engineer.

In question ten, the students were asked to rank ten different statements about why they chose to study engineering. The alternatives contained statements like *Technology plays an important role in society*, *Engineers make more money than most other professionals*, and *My parents want me to be an engineer.* For the complete list of statements, see Appendix A. Options were "not a reason", "minimal reason", "moderate reason" and "major reason". There were no systematic differences between the male and female responses. The only visible differences were in the two statements *My parents want me to be an engineer* and *An engineering degree will guarantee me a job when I graduate*, as shown in figure 13 and 14, respectively. The males did not identify the influence of their parents as a strong motivation for choosing engineering, while the females did. The females indicated, to a larger extent than the males, that an engineering degree would guarantee them a job after graduation.

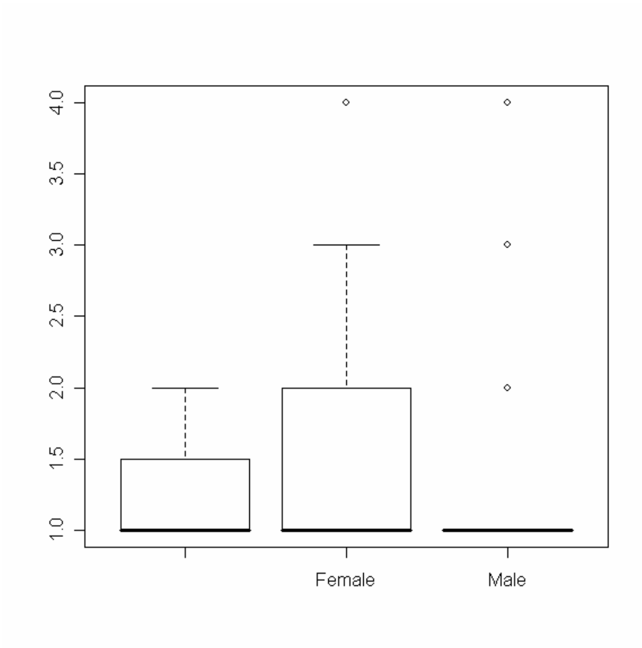


Figure 13. Box diagrams for the statement *My parents want me to be an engineer*, where the numerical value 1 corresponds to 'not a reason', 2 corresponds to 'minimal reason', 3 a 'moderate reason' and 4 corresponds to 'major reason'. A small number of outliners are visible, both for females and males. The unmarked box diagram to the left corresponds to students that have not indicated their gender in the survey.

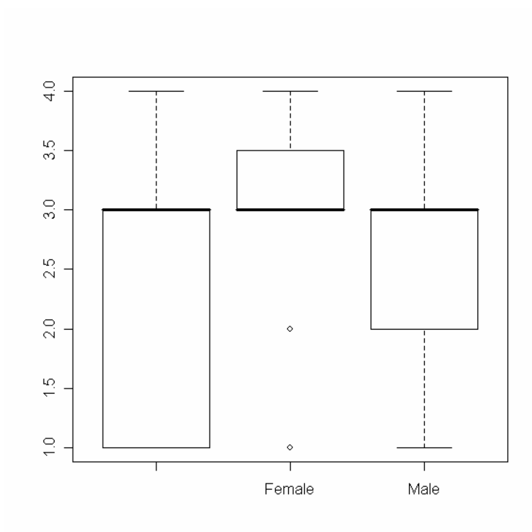


Figure 14. Box diagram for the statement *An engineering degree will guarantee me a job when I graduate*, where the numerical value 1 corresponds to 'not a reason', 2 corresponds to 'minimal reason', 3 'moderate reason' and 4 corresponds to 'major reason'. A small number of outliners are visible for the female group. The unmarked box diagram to the left corresponds to students that have not indicated their gender in the survey.

In question twelve, the students were asked to rate their own traits as compared to their classmates'. There were a total number of eleven traits, such as 'self confidence', 'leadership ability', 'math ability' etc, and the ratings were 'lowest 10 %', 'below average', 'average', 'above average' and 'highest 10 %'. For the full list of traits, see Appendix A. There were no significant differences in the answers that could be traced back to gender other than regarding 'public speaking ability' and 'computer skills', where the males rated their own skills higher than the females, see figures 15 and 16.

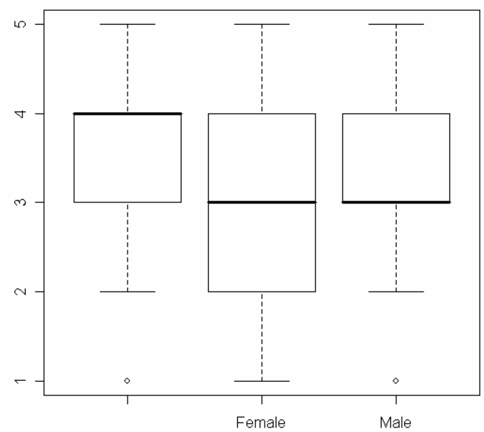


Figure 15. Box diagram for the trait *Public speaking ability*, where the grading 'lowest 10 %' corresponds to the numerical value 1, 'below average' to 2, 'average' to 3, 'above average' to 4 and 'highest 10 %' to 5. The unmarked box diagram to the left corresponds to students that have not indicated their gender in the survey.

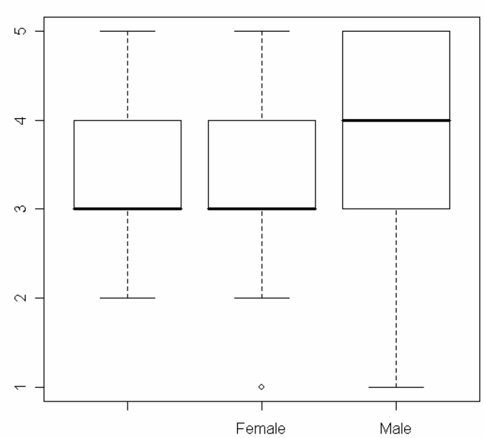


Figure 16. Box diagram for the trait *Computer skills*, where the grading 'lowest 10 %' corresponds to the numerical value 1, 'below average' to 2, 'average' to 3, 'above average' to 4 and 'highest 10 %' to 5. The unmarked box diagram to the left corresponds to students that have not indicated their gender in the survey.

In addition, students where asked to choose the five most important words (out of a list of twenty) that would be important for a working engineer. For the full list, see Appendix A (Q41). In figure 17, the results are displayed for the females and males respectively.

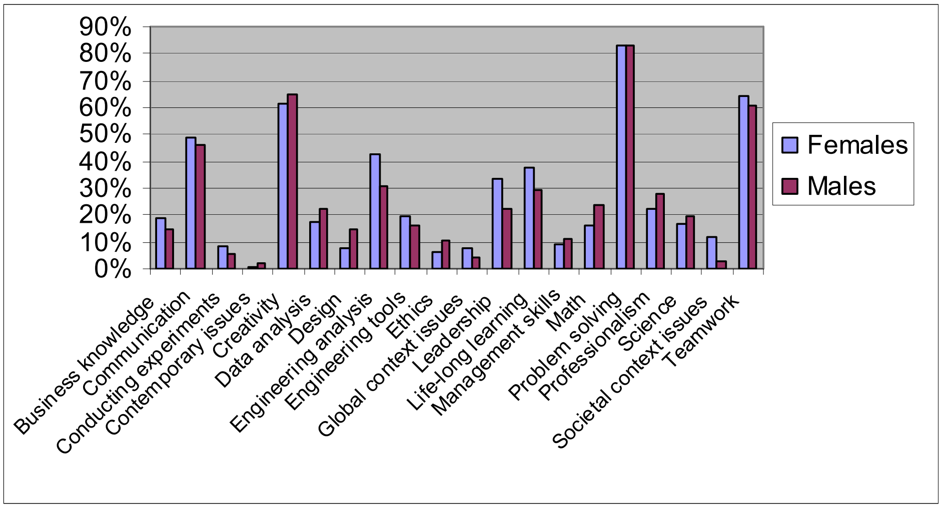


Figure 17. The distribution of the most important terms for a working engineer, where the students were asked to check five out of twenty terms. The diagram shows the amount of students that have checked each word.

It is noticeable that the four most frequent terms are common for the two groups and moreover, that their relative occurrence is very similar. The term that the students rated most important for engineering was 'Problem solving'. About 83% of both males and females checked this word as one of the most important. The three following most frequent words were 'Creativity', 'Teamwork' and 'Communication', and their relative occurrence are listed below in table 17. Both men and women rank 'Contemporary issues' as least important, 0.9% for the females and 2.3% for the males, which may be due to the students' lack of understanding of the English term. The males rank 'Societal context issues' very low (2.6%), while for the women the corresponding number is 12%. Other terms with low rate are 'Conducting experiments', 'Ethics' and 'Global context issues'.

Table 17. The six most frequent words for females and males.

	Term	Females (%)	Males (%)
1	Problem solving	83.3	82.8
2	Creativity	61.1	64.7
3	Teamwork	63.9	60.8
4	Communication	49.1	46.0

Concept map debrief summary

After the participant had finished the concept map they where asked to answer some questions regarding the terms used. There were 17 women and 93 men in this part of the analysis.

The first question was: *Which terms on the list most represent university-level courses you have taken or are currently taken?* Most of the students (both female and male) answered "mathematics", Women stated "teamwork" more than the men, 59% versus

36%. Only about a third of the students said that they had associated the term "engineering" with their education, 29% versus 26%.

The second question was: *Which terms on the list most represent your educational experiences outside of the classroom?* Both groups had the term "communication" at the highest rate, female 71% and 44% for male.

The third question was: *Which terms on the list least represent university-level courses you have taken or are currently taken?* The most frequent concept for both groups was "ethics", 53% of female and 34% of the male. Many interviewees also thought that society were not frequently represented in their university education, 41% respectively 18% for the groups.

We counted the occurrence of the same concept in question1 and question 2, for the female group the mean value was 1.5 concepts, and for the male group the corresponding figure was 0.5. The same concept appeared in both question 2 and question 3 for 0.4 for the female group and 0.3 for the male group. That means that not so many students associate the concepts that are not frequent in university education with engineering experiences outside of the university environment.

Table 18 Frequency of terms from concept map list which "*most represent university-level courses you have taken or are currently taken?"*

Concept map list terms, Q1	Female	Percent	Male	Percent
mathematics	13	76.5%	58	62.4%
theory	11	64.7%	44	47.3%
analysis	10	58.8%	40	43.0%
teamwork	10	58.8%	34	36.6%
technology	6	35.3%	33	35.5%
communication	5	29.4%	31	33.3%
design	5	29.4%	30	32.3%
engineering	5	29.4%	25	26.9%
modelling	5	29.4%	22	23.7%
complexity	4	23.5%	20	21.5%
research	4	23.5%	17	18.3%
science	4	23.5%	15	16.1%
economics	2	11.8%	12	12.9%
implementation	2	11.8%	11	11.8%
international	2	11.8%	10	10.8%
multidisciplinary	2	11.8%	8	8.6%
society	2	11.8%	8	8.6%
uncertainty	2	11.8%	7	7.5%
environment	1	5.9%	6	6.5%
experimentation	1	5.9%	6	6.5%
safety	1	5.9%	5	5.4%
sustainable	1	5.9%	5	5.4%
ethics	0	0.0%	3	3.2%
impact	0	0.0%	2	2.2%
innovation	0	0.0%	2	2.2%
judgment	0	0.0%	1	1.1%
Total number of answers	98		455	
Number of answers/participant	5.8		4.9	

Table 19. Frequency of terms from concept map list which "*most represent your educational experiences outside of the classroom"*

Concept map list terms, Q2	Female	Percent	Male	Percent
communication	12	70.6%	41	44.1%
economics	9	52.9%	40	43.0%
teamwork	8	47.1%	23	24.7%
impact	4	23.5%	23	24.7%
international	4	23.5%	20	21.5%
society	4	23.5%	13	14.0%
design	3	17.6%	11	11.8%
environment	3	17.6%	10	10.8%
ethics	3	17.6%	9	9.7%
safety	3	17.6%	8	8.6%
complexity	2	11.8%	8	8.6%
experimentation	2	11.8%	7	7.5%
implementation	2	11.8%	6	6.5%
mathematics	2	11.8%	6	6.5%
multidisciplinary	2	11.8%	6	6.5%
analysis	1	5.9%	5	5.4%
judgment	1	5.9%	5	5.4%
research	1	5.9%	5	5.4%
science	1	5.9%	4	4.3%
uncertainty	1	5.9%	4	4.3%
engineering	0	0.0%	3	3.2%
innovation	0	0.0%	3	3.2%
modelling	0	0.0%	3	3.2%
sustainable	0	0.0%	3	3.2%
technology	0	0.0%	2	2.2%
theory	0	0.0%	2	2.2%
Total number of answers	68		270	
Number of answers/participant	4.0		2.9	

Table 20. Frequency of terms from concept map list which "*least represent university-level courses you have taken or are currently taken?*"

Concept map list terms. Q3	Female	Percent	Male	Percent
Ethics	9	52.9%	32	34.4%
Society	7	41.2%	23	24.7%
Environment	6	35.3%	23	24.7%
Design	4	23.5%	17	18.3%
Innovation	4	23.5%	17	18.3%
International	4	23.5%	15	16.1%
Economics	2	11.8%	11	11.8%
Impact	2	11.8%	10	10.8%
Judgment	2	11.8%	10	10.8%
Teamwork	2	11.8%	10	10.8%
communication	1	5.9%	7	7.5%
experimentation	1	5.9%	7	7.5%
implementation	1	5.9%	6	6.5%
Modelling	1	5.9%	6	6.5%
Research	1	5.9%	5	5.4%
Analysis	0	0.0%	5	5.4%
Complexity	0	0.0%	4	4.3%
Engineering	0	0.0%	3	3.2%
Mathematics	0	0.0%	3	3.2%
multidisciplinary	0	0.0%	3	3.2%
Safety	0	0.0%	2	2.2%
Science	0	0.0%	2	2.2%
Sustainable	0	0.0%	2	2.2%
Technology	0	0.0%	2	2.2%
Theory	0	0.0%	2	2.2%
Uncertainty	0	0.0%	1	1.1%
Total number of answers	47		228	
Number of answers/participant	2.8		2.5	

For Question 1 and Question 2 the female group had a mean value of 1.5 concepts in both question and the male group had 0.5

For Question 1 and Question 3 the female group had a mean value of 0.1 concept in both question and the male group had 0.2

For Question 2 and Question 3 the female group had a mean value of 0.4 concept in both question and the male group had 0.3

Perceptions of professional practice

With regard to perceptions of professional practice, there were no differences attributable to gender. In question 13 of the survey, participants were asked to rate how important they considered different skills and abilities for a becoming a successful engineer. The rating was 'not important', 'somewhat important', 'very important' and 'crucial'. There no observable differences in the female and male answers, other than a larger spread in the male answers regarding 'self confidence' and 'communication skills'. The males rated communication skills as slightly more important than the females.

Discussion

As reported in Studies A-E above the Stepping Stones project has provided a rich data set for exploring conceptions of engineering from a Swedish perspective.

In terms of continuing work, we anticipate we will undertake the following analyses:

> **Surveys**: An analysis by discipline.
>
> **Concept maps**: Analysing how the concept maps develop over time, using the explanogram representations. For example, examining the sequences graphically and reformulating them as stories or narratives that could be further analyzed. For example, could we then tell the categories' different stories? Some of the participants forgot or excluded certain words. Is there a pattern to this or is it just neglect to check that all concepts were used? How can we relate this to the debrief information? Especially interesting would be relating these sequences with questions one and three from the concept map debrief, that ask students to relate the terms used in the mapping task to their university courses.
>
> **Interviews with surveys**: An analysis of question 38 of the survey with respect to questions 1, 2 and 5 in the interview. For example, it should be possible to create a list of terms students associate with engineering and then compare these with the responses in the interview. Also, at this stage, no aggregation of the terms from the survey has been performed. Early analyses of the survey, reported here, indicate that "problem solving" and "mathematics" are terms that participants frequently use for describing engineering. In addition, it would be useful to continue the analysis of the photo elicitation interviews.
>
> **Case studies**: We are currently discussing an analysis of a subset of participants across multiple data sources.

Acknowledgements

The *Stepping Stones* project was funded by Rådet för högre utbildning (the Swedish Council for Renewal of Higher Education) and by Myndigheten för nätverk och samarbete inom högre utbildning (the Swedish Agency for Networks and Cooperation in Higher Education). It was run within the context of the Nationellt ämnesdidaktiskt Centrum för Teknikutbildning i Studenternas Sammanhang project (CeTUSS), a national centre for pedagogical development in technology education in a societal and student oriented context. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of any of these supporting bodies.

The use of a "critical incident" interview for this study was influenced by discussions with Carsten Schulte and Llewellyn Mann, and we thank them for their time and interest.

References

Becker, H. S. (1974). "Photography and Sociology" Studies in the Anthropology of Visual Communication 1, 3-26. http://lucy.ukc.ac.uk/becker.htm.

Beggeren, K-F., Brodeur, D., Crawley, E.F., Ingemarsson, I., Litant, W.T.G., Malmqvist., J. & Őstlund, S. (2003) CDIO: An international initiative for reforming engineering education, World Transactions on Engineering and Technical Education, Vol.2, No.1.

Besterfield-Sacre, ME, Atman, CJ, and Shuman, LJ, "Engineering Student Attitudes Assessment," Journal of Engineering Education, 87(2), April 1998, pp. 133-141.

Besterfield-Sacre, M.E., M. Moreno, L.J. Shuman, and C.J. Atman, "Gender and Ethnicity Differences in Freshmen Engineering Student Attitudes: A Cross-Institutional Study," Journal of Engineering Education, 90(4), October 2001, pp. 477 - 489.

Cunningham, C.M., Lachapelle, C. & Lindgren-Streicher, A. (2005). "Assessing elementary school students' conceptions of engineering and technology." Proceedings of the ASEE Annual Conference.

Dahlgren, L.O. & Pramling, I. (1985). "Conceptions of knowledge, professionalism and contemporary problems in some professional academic subcultures." *Studies in Higher Education*, Vol 10 (2), pp. 163-173.

Downey, G. and Lucena, J. (2003). "When Students Resist: Ethnography of a Senior Design Experience in Engineering Education." *International Journal of Engineering Education*, 19 (1), pp.168-176.

Downey, G.L. and Lucena, J.C. (1997). "Engineering Selves: Hiring into a Contested Field of Eduacation." In G.L. Downey and J. Dumit (eds), Cyborgs and Citadels: Anthropological Interventions in Emerging Sciences and Technologies (pp. 117-142). Santa Fe, NM: The SAR Press.

Downey, G.L. and Lucena, J.L. (1994). "Engineering Studies." In S. Jasanoff, G. Markle, J. Petersen, and T. Pinch (eds), Handbook of Science, Technology, and Society (pp. 167-188). Newbury Park, CA: SAGE.

Edwards, J., & Fraser, K. (1983). Concept maps as reflections of conceptual understanding. *Research in Science Education, 13*, 19-26.

Eris, O., Chen, H., Bailey, T., Engerman, K., Loshbaugh, H. G., Griffin, A, Lichenstein, G., and Cole, A *Development of the Persistence in Engineering (PIE) Survey Instrument* (2005) Proceedings of ASEE conference

Eris et al (2007). "A Preliminary Analysis of Correlates of Engineering Persistence: Results form a Longitudinal Study." *Proceedings of the American Society for Engineering Education*, Oahu, Hawaii.

Extraordinary Women Engineers Coalition (EWEC) (2005). Extraordinary Women Engineers Final Report. http://www.engineeringwomen.org/pdf/EWEPFinal.pdf

Fincher, S. & Tenenberg, J. Using theory to inform capacity-building: Bootstrapping communities of practice in computer science education research. *Journal of Engineering Education*, 95(4):265-278,

Flanagan, J. C. (1954) The Critical Incident Technique *Psychological Bulletin*

Harper, D. *Talking about pictures: a case for photo elicitation* (2002) Visual Studies, vol 17 no. 1 pp 13-26

Högskoleverket (2006). Studying in higher education (Engelska). ISBN: 91-85027-51-0.

Hutchinson, M.A., Follman, D.K. & Sumpter, M. (2006). "Factors Influencing the Self-Efficacy Beliefs of First-Year Engineering Students." Journal of Engineering Education, 95 (1), pp. 39-47.

Jonassen, D., Strobel, J. & Beng Lee, C. (2006). "Everyday Problem Solving in Engineering: Lessons for Engineering Education." *Journal of Engineering Education*, April, pp. 139-151.

Klein G., Calderwood, R., MacGregor, D (1989) *Critical Decision Method for Eliciting Knowledge* IEEE Transactions on Systems, Man and Cybernetics vol.19 no.3 pp462-472

Klein, G (1999) *Sources of Powe.r* MIT Press

Knight, M. & Cunningham, C. (2004). "Draw an Engineering Test (DAET): Development of a Tool to Investigate Students' Ideas about Engineers and Engineering." Proceedings of the ASEE Annual Conference.

Lethbridge, T.C. (2000). "What knowledge is important to software professional?" *Computer*, Vol. 33, Issue 5, pp. 44-50.

Maury, C. (2004). An External View on the Swedish System of Engineering Education. Contribution to the IVA Project – Engineers of Tomorrow. Royal Swedish Academy of Engineering Sciences (IVA).

Mosborg, S., R. Adams, R. Kim, C. J. Atman, J. Turns & M. Cardella (2005). "Conceptions of the Engineering Design Process: An Expert Study of Advanced Practicing Professionals." Proceedings of the Annual American Society of Engineering Education Conference, Portland, June.

Newstetter, W.C. and McCracken, W.M. (2001). "Novice conceptions of design: Implications for the design of learning environments. In C. M. Eastman, W. M.

McCracken, & W. Newstetter (Eds.), *Design Learning and Knowing: Cognition in Design Education*. (pp.63-78). New York: Elsevier.

Novak, J. D. (1998). *Learning, creating, and using knowledge: Concept maps as facilitative tools in schools and corporations*. Mahwah, NJ: Lawrence Erlbaum Associates.

Pears, A. N, & Erickson, C. (2003) "Enriching online learning resources with 'explanograms'" Proceedings of first international symposium on information and communication technologies

Pears, A.N., Pettersson, L. & Erickson, C. (2003) "Enriching online learning resources with 'explanograms'"ACM SIGCSE Bulletin, Volume 35, Issue 3.

Posner, G.J., et al (1982). Accomodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, 66, pp. 211-227.

Prosser, J. (1998). *Imaged-based research.* London: Falmer Press.

Ryan, G.W. & Bernard, H.R. (2003) Techniques to Identify Themes, *Field Methods*, Vol. 15, no.1, pp. 85-109.

Seymour, D. & Hewitt, N.M. (2006). *Talking about Leaving: Why Undergraduates Leave the Sciences*. Boulder, CO: Westview Press

Sinatra, G.M. and Pintrich, P.R. (eds) (2003). *Intentional conceptual change*. New Jersey, Lawrence Erlbaum Associates.

Turns, J., Temple, J. & C. J. Atman (2000a). "Students' Conceptions of their Engineering Discipline: A Word Association Study". Proceedings of the Annual American Society for Engineering Education Conference.

Turns, J., Atman, Cynthia J., Adams, Robin *Concept Maps for Engineering Education: A Cognitively Motivated Tool Supporting Varied Assessment Functions* (2000b) IEEE Transactions on Education vol 43 no 2 pp 164-173

Walther, J. and Radcliffe, D. (2006). "Engineering Education: Targeted Learning Outcomes or Accidental Competencies?" *Proceedings of the Annual American Society for Engineering Education* Conference, June, Chicago.

Image References

Image A Date: 04.21.1970 Title: Ames engineers Allen Faye, Merrill Mead and John "Jack" Boyd discuss aircraft design and handling ID: A70-1881 Credit: NASA Ames Research Center (NASA-ARC) http://ails.arc.nasa.gov/CumulusImages/Previews/PCD2378/Photos/768%20x%20512/37.jpg

Image B Credit: Practical Action/Zul. Practical Action is registered charity No 247257, http://www.itdg.org/

Image C Credit: Peter Kyberd

All images used with permission.

Appendices

A. Survey questions, as used
B. Changes made to APS survey for Swedish context
C. Concept map protocol
D. Interview protocol (critical incident & photo elicitation)
E. Image Set
F. APS PIE Constructs in *Stepping Stones* Survey
G. Construct analysis from *Stepping Stones* Survey
H. Institutional Characterizations
I. Categories for coding programs of study / disciplines
J. Concept map debrief (internal analysis)

Appendix A: Survey questions, as used

The *Stepping Stones* survey was adapted, with permission, from the Academic Pathways Survey (APS), developed by the Center for the Advancement of Engineering Education (http://www.engr.washington.edu/caee/). This version of the survey was solely for use within Sweden.

1 When did you begin at your current University?

○ 2006

○ 2005

○ 2004

○ 2003

○ 2002

○ 2001 or earlier

2 What is your expected year of graduation from university?

○ 2007

○ 2008

○ 2009

○ 2010

○ 2011

○ 2012

○ 2013

○ 2014 or later

3 Did you study elsewhere (universitet/högskola) before coming to your current University? If so, how many years did you complete before you transferred to your current University? If none, please jump to question 6.

○ None

○ One year completed

○ Two years completed

○ Three years completed

○ Four years completed

○ More than four years completed

4 How many study points (högskolepoäng) did you gain from this study?

5 Where did you study? (name and country of most recent universitet/högskola)

6	What kind of program are you taking?
○	3 year program
○	4 year program
○	4.5 year program
○	5 year program
	Other (write in)

7	Do you intend to complete your engineering degree?
○	Definitely Not
○	Probably Not
○	Not Sure
○	Probably Yes
○	Definitely Yes

8 What kind of study program are you taking?

○ Aerospace engineering & mechanics

○ Astrophysics

○ Bio-based products engineering

○ Biomedical engineering

○ Biosystems & agricultural engineering

○ Chemical engineering

○ Chemistry

○ Civil engineering (väg och vatten)

○ Computer engineering

○ Computer science

○ Electrical engineering

○ Geological engineering

○ Geology

○ Geophysics

○ Information technology

○ Materials science & engineering

○ Mathematics

○ Mechanical engineering

○ Mediateknik/Interaktion och design

○ Software engineering

○ Physics

○ Statistics

○ Arts & humanities

○ Education

○ Other (write in)

9 Do you intend to work as an engineer, conduct research in engineering, or teach engineering for at least 3 years after graduation?

○ Definitely Not

○ Probably Not

○ Not Sure

○ Probably Yes

○ Definitely Yes

10 We are interested in knowing why you are studying engineering now. Please indicate below the extent to which the following reasons apply to you:	Not a reason	Minimal Reason	Moderate Reason	Major Reason
Technology plays an important role in solving society's problems	○	○	○	○
Engineers make more money than most other professionals	○	○	○	○
My parent(s) would disapprove if I chose a degree other than engineering	○	○	○	○
Engineers have contributed greatly to fixing problems in the world	○	○	○	○
Engineers are well paid	○	○	○	○
Engineering is an occupation that is respected by other people	○	○	○	○
My parent(s) want me to be an engineer	○	○	○	○
An engineering degree will guarantee me a job when I graduate	○	○	○	○

Engineers are creative problem solvers	○	○	○	○
A person working at/from a university has encouraged and/or inspired me to study engineering	○	○	○	○
A non-university affiliated mentor has encouraged and/or inspired me to study engineering	○	○	○	○

11	Please indicate how strongly you disagree or agree with each of the statement:	Disagree Strongly	Disagree	Agree	Agree Strongly
	I prefer studying in a group to studying by myself	○	○	○	○
	I prefer working as part of a team to working alone	○	○	○	○
	I get along well with others in study situations	○	○	○	○
	I am a collaborative person	○	○	○	○
	Creative thinking is one of my strengths	○	○	○	○
	I am familiar with what a practicing engineer does	○	○	○	○
	I am skilled at solving problems that can have multiple solutions	○	○	○	○

12	Rate yourself on each of the following traits as compared to your classmates. We want the most accurate estimate of how you see yourself. (Mark one in each row.)	Lowest 10%	Below Average	Average	Above Average	Highest 10%
	Self confidence (social)	○	○	○	○	○
	Leadership ability	○	○	○	○	○
	Public speaking ability	○	○	○	○	○
	Math ability	○	○	○	○	○
	Science (naturvetenskap) ability	○	○	○	○	○
	Computer skills	○	○	○	○	○
	Communication skills	○	○	○	○	○

Ability to apply math and science principles in solving real world problems	○	○	○	○	○
Business ability	○	○	○	○	○
Ability to perform in teams	○	○	○	○	○
Critical Thinking skills	○	○	○	○	○

13	How important do you think each of the following skills and abilities is to becoming a successful engineer? (Mark one in each row.)	Not Important	Somewhat Important	Very Important	Crucial
	Self confidence (social)	○	○	○	○
	Leadership ability	○	○	○	○
	Public speaking ability	○	○	○	○
	Math ability	○	○	○	○
	Science (naturvetenskap) ability	○	○	○	○
	Computer skills	○	○	○	○
	Communication skills	○	○	○	○
	Ability to apply math and science principles in solving real world problems	○	○	○	○
	Business ability	○	○	○	○
	Ability to perform in teams	○	○	○	○

14	Please rate your satisfaction with this institution on each of the aspects of campus life listed below. If you do not have experience with this aspect, mark N/A.	Very Dissatisfied	Dissatisfied	Satisfied	Very Satisfied	N/A
	Quality of instruction by lecturing staff (lärare)	○	○	○	○	○
	Quality of advising by lecturing staff (lärare)	○	○	○	○	○
	Availability of lecturing staff (lärare)	○	○	○	○	○

	Quality of instruction by teaching assistants (handledare)	○	○	○	○	○
	Quality of advising by teaching assistants (handledare)	○	○	○	○	○
	Availability of teaching assistants (handledare)	○	○	○	○	○

15	Please rate your satisfaction with each of the following at this institution. If you do not use the service or facility, mark N/A.	Very Dissatisfied	Dissatisfied	Satisfied	Very Satisfied	N/A
	Computer facilities	○	○	○	○	○
	Libraries	○	○	○	○	○
	Classrooms	○	○	○	○	○
	Supplemental instruction	○	○	○	○	○
	Academic advising	○	○	○	○	○
	Laboratories	○	○	○	○	○

16 *From the start of the Fall term*, how often have you taken courses which required your engagement in individual and/or group projects?

○ Never

○ Rarely

○ Occasionally

○ Frequently

17	Think about the engineering classes you have taken since the beginning of the Spring term (engineering, math, and science classes). Indicate how often you:	Never	Rarely	Occasionally	Frequently	N/A
	Came late to engineering class	○	○	○	○	○
	Skipped engineering class	○	○	○	○	○

	Turned in engineering assignments that did not reflect your best work	○	○	○	○	○
	Turned in engineering assignments late	○	○	○	○	○
	Thought engineering classes were boring	○	○	○	○	○

		Never	Rarely	Occasionally	Frequently	N/A
18	Think about the elective classes (courses other than engineering, math and science) you have taken since the beginning of the Fall term. Indicate how often you: (Mark N/A if you have not taken any elective classes.)					
	Came late to elective class	○	○	○	○	○
	Skipped elective class	○	○	○	○	○
	Turned in elective assignments that did not reflect your best work	○	○	○	○	○
	Turned in elective assignments late	○	○	○	○	○
	Thought elective classes were boring	○	○	○	○	○

19	How often have you interacted with the following people since the beginning of the Fall term (e.g. by phone, e-mail, Instant Messenger, or in person)? (Mark one for each item.)	Never	1-2 times per Term	1-2 times per Month	Once per Week	2-3 Times per Week	Daily
	Lecturing staff (lärare) during class	○	○	○	○	○	○
	Lecturing staff (lärare) during visiting hours	○	○	○	○	○	○
	Lecturing staff (lärare) outside of class or visiting hours	○	○	○	○	○	○
	Teaching Assistants (handledare) during class	○	○	○	○	○	○
	Teaching Assistants (handledare) during visiting hours	○	○	○	○	○	○
	Teaching Assistants (handledare) outside of class or visiting hours	○	○	○	○	○	○

20 What portion of the courses you have taken from the start of this academic year has been taught primarily by non-Academic staff (for example teaching assistants or technicians)?

○ None

○ Very little

○ Less than half

○ About half

○ More than half

○ All or nearly all

21	From the start of the Fall term, what portion of your classes used the following teaching methods?	None	Very little	Less than half	About half	More than half	All or nearly all
	Lectures	○	○	○	○	○	○
	Individual Projects	○	○	○	○	○	○
	Team Projects	○	○	○	○	○	○
	Labs	○	○	○	○	○	○
	Seminars	○	○	○	○	○	○

22 To what extent have your courses required your engagement in individual and/or group projects?

○ Too Few

○ Enough

○ Too many

23 Some people are involved in non-engineering activities on or off campus, such as hobbies, community or church organizations, campus publications, student government, sports, etc. How important is it for you to be involved in these kinds of activities?

○ Not Important

○ Somewhat Important

○ Very Important

○ Essential

24 How often are you involved in the kinds of non-engineering activities described above?

○ Never

○ Rarely

○ Occasionally

○ Frequently

25 Thinking about your university experience since the beginning of the Fall term, please indicate how much pressure you are feeling related to the following:	No Pressure	Reasonable Pressure	Extreme Pressure
Course load (amount of course material being covered)	○	○	○
Course pace (the speed at which the course material is being covered)	○	○	○
Balance between social and academic life	○	○	○

26 How well are you meeting the workload demands of your coursework?

○ I am meeting all of the demands easily

○ I am meeting all of the demands, but it is hard work

○ I am meeting most of the demands, but cannot meet some

○ I can meet some of the demands, but cannot meet most

○ I cannot meet any of the demands

27 How stressed do you feel in your coursework right now?

○	No stress
○	Some stress
○	Reasonable stress
○	Significant stress
○	Extreme stress

28 Do you have any concern about your ability to finance your living during your university education?

○ None (I am confident that I will have sufficient funds)

○ Some (but I probably will have sufficient funds)

○ Major (not sure if I will have sufficient funds to complete university)

29	How do you meet your university expenses (e.g. books, living expenses)?	None	Very little	Less than half	About half	More than half	All or nearly all
	Self (income)	○	○	○	○	○	○
	Self (savings)	○	○	○	○	○	○
	Parents and family	○	○	○	○	○	○
	Employer support	○	○	○	○	○	○
	Scholarships and grants	○	○	○	○	○	○
	Loans	○	○	○	○	○	○

30 Do you have family members who are working engineers?

○ Yes

○ No

31	Do you have close friends who are working engineers?
○	Yes
○	No

32 How much exposure have you had to a professional engineering environment as a visitor, intern (praktikant), or employee?

○ No exposure

○ Limited exposure

○ Moderate exposure

○ Extensive exposure

33	About how many hours do you spend in a typical 7-day week doing each of the following?	0	1-5	6-10	11-15	16-20	21-25	26-30	More than 30
	Preparing for courses (studying, reading, writing, doing homework or lab work, analyzing data, rehearsing, and other academic activities)	○	○	○	○	○	○	○	○
	Working for pay	○	○	○	○	○	○	○	○
	Participating in co-curricular activities (organizations, campus publications, student government, sports, etc.)	○	○	○	○	○	○	○	○
	Relaxing and socializing (watching TV, partying, exercising, etc.)	○	○	○	○	○	○	○	○
	Providing care for dependents living with you (parents, children, partner, etc.)	○	○	○	○	○	○	○	○
	Commuting to class (driving, walking, etc.)	○	○	○	○	○	○	○	○

34 Please rate the overall quality of your university experience so far:

○ Very dissatisfied

○ Dissatisfied

○ Satisfied

○ Very satisfied

35 What did you do this past summer that was particularly important to you?

36 Did your summer experience advance your interest in studying engineering?

○ Yes

○ No

37 Did you participate over the summer in any of the following? (Mark all that apply.)

○ Engineering related internship/job

○ Engineering related research

○ Engineering related coursework

○ N/A

38 In the space provided, list 5 terms you would use to describe "engineering":

39 In the space provided, list 5 terms you would use to describe "design":

40 In the space provided, list 5 activities you think engineers do at work.

41 Of the 20 items below, please put a check mark next to the five you think are MOST IMPORTANT for working engineers.

○ Business knowledge

○ Communication

- ○ Conducting experiments
- ○ Contemporary issues
- ○ Creativity
- ○ Data analysis
- ○ Design
- ○ Engineering analysis
- ○ Engineering tools
- ○ Ethics
- ○ Global context issues
- ○ Leadership
- ○ Life-long learning
- ○ Management skills
- ○ Math
- ○ Problem solving
- ○ Professionalism
- ○ Science
- ○ Societal context issues
- ○ Teamwork

42 Your sex:

- ○ Female
- ○ Male

43 Status:

◯ Swedish native

◯ Swedish citizen

◯ Permanent resident (permanent uppehållstillstånd)

◯ International student (please specify nationality)

◯ None of the above

44	If you are an international student please specify your nationality.

45	Do any of your immediate family members hold an engineering degree? (Mark all that apply)
◯	No
◯	Yes, both parents
◯	Yes, father only
◯	Yes, mother only
◯	Yes, brother(s) or sister(s)

46 What is the highest level of education that your mother completed? (Mark one box)

◯ Did not finish gymnasiet

◯ Graduated from gymnasiet (tog studenten)

◯ Attended högskola/universitet but did not complete degree

◯ Completed a kandidatexamen

◯ Completed a magisterexamen

◯ Completed a civilingenjörexamen

○ Completed a doktorsexamen

47 What is the highest level of education that your father completed? (Mark one box)

○ Did not finish gymnasiet

○ Graduated from gymnasiet (tog studenten)

○ Attended högskola/universitet but did not complete degree

○ Completed a kandidatexamen

○ Completed a magisterexamen

○ Completed a civilingenjörexamen

○ Completed a doktorsexamen

48 What is your best estimate of your parents' total income last month? Consider income from all sources before taxes. (Mark one)

○ Less than 5,000 SEK

○ 5,000-7,999 SEK

○ 8,000-10,999 SEK

○ 11,000-13,999 SEK

○ 14,000-18,999 SEK

○ 19,000-23,999 SEK

○ 24,000-28,999 SEK

○ 29,000-33,999 SEK

○ 34,000-38,999 SEK

○ 39,000-48,999 SEK

○ 49,000-58,999 SEK

○ 59,000-68,999 SEK

○ 70,000-88,999 SEK

○ 89,000 SEK or more

Appendix B: Changes made to APS survey for Swedish context

In its originating context the APS was used as an instrument in a longitudinal study.

For the purposes of the *Stepping Stones* survey, we preserved the item codes, so that data from the US and Sweden might be compared at some future point. However, this version of the survey was solely for use within Sweden. We made the following adaptations:

Global changes

- The term "university" was substituted for "college" throughout
- The term "lecturing staff" was substituted for "faculty" throughout – and later modified for correct language
- The phrase "social fraternity or sorority" was deleted throughout
- All references to time – changed to "fall" term (unless summer was explicitly referenced)

Item changes

	Stepping Stones variations	APS originals
1	New question unique to this study "When did you begin at your current university?" (Rationale – needed a "start point" to clarify what kind of program (3,4,5 year programs) – culture issue)	
2	Unchanged	
3	"Did you study elsewhere (universitet / högskola) before coming to your current University? If so, how many years did you complete before you transferred to your current University?" Revision - clarify whether or not military service "counts" (culture issue) Clarify "study" via use of universitet / högskola	"How many years of university did you complete before you transferred to the University of X?"
4	Inserted: "How many study points did you gain from this study?"	

5	Required write-in rather than drop-down list "Where did you study? (name of institution)" Revision – clarification on "institution" (language issue) – replaced with "universitet / högskola" Revision – account for number of international students: "Where did you study? (name and country of most recent universitet / högskola)"	
6	Addition of new question "What kind of program are you taking?" (Rationale – need to distinguish 3, 4, 5 year programs)	
7	"Do you intend to complete your engineering degree?" Revision – note deleted "civilingenjorsexamn degree?" due to existence of question 4a (kind of degree)	"Do you intend to complete a major in engineering?"
8	"What program are you taking?" Added write-in box for "Other" (so list can be inclusive to all programs) Revision – clarification to "kind of study program" (language issue) Addition of "software engineering" and "mediateknik / interaction och design" (a noticeable field in Sweden) Deleted "Social Science" has having no meaning in Swedish context.	"What do you intend to major in?"
	Deleted. Inappropriate to Swedish context	"If you intend to DOUBLE MAJOR, what is the second major you intend to complete?"

9	"Do you intend to work as an engineer, conduct research in engineering, or teach engineering for at least 3 years after graduation?" Revision –clarification over "practice" (language issue)	"Do you intend to practice, conduct research in, or teach engineering for at least 3 years after graduation?"
	Deleted. It would be effectively impossible in Sweden to pursue non-engineering graduate education if you have a first degree in engineering.	"If you are thinking of going to graduate school NOT IN ENGINEERING, please mark your most probable area of study"
10	Changed item 38508 to "A member of the academic staff, teaching assistant or other university affiliated person …" Changed item "My parent(s) would disapprove if I chose a degree other than engineering" A person working at/from a university has encouraged and/or inspired me to study engineering Language and cultural issues	"A faculty member, academic advisor, teaching assistant or other university affiliated person …" My parent(s) would disapprove if I chose a major other than engineering A member of the academic staff, teaching assistant or other university affiliated person has encouraged and/or inspired me to study engineering
11	Unchanged	
12	Unchanged Revision to item – clarification of "science ability" to "Science (naturvetenskap) ability" (culture / language issue).	
13	Unchanged Revision to item – clarification of "science ability" to "Science (naturvetenskap) ability" (culture / language issue).	
14	Unchanged (except global "faculty" substitution, as above) Revision – clarification regarding lecturing staff (lärare) and teaching assistants (handledare) (language and cultural issue)	
15	Revision – clarification regarding "tutoring" (language and cultural issue) – changed to "supplemental instruction"	

16	Unchanged Did not revise “project” (language issue – projects vs. assignments). Rationale – likely that US students had similar issues interpreting what is a project and what is homework – the question is more about individual vs. group work	
17	Did not revise “engineering classes” to compulsory classes since there are apparently many levels of mandatory courses and the issue is less about what is mandatory and more about a particular course topic (engineering/math/sci)	
18	Changed “Think about the elective (courses other than engineering, math, and science) classes you have taken …” “elective” (cultural / language issue)	“Think about the liberal arts classes you have taken …”
19	Revision – changed “spring” to “fall”; Added clarification to lecturing staff and teaching assistants; changed “office hours” to “visiting hours” (cultural issue)	
20	Revision – clarification regarding “graduate student” to “What portion of the courses you have taken since the start of this academic year have been taught primarily by non-Academic staff (for example teaching assistants or technicians” (cultural issue). There was a request to add “I don’t know” since it is believed that many students will not know if lecturers have graduated or not. We chose not to do this since it changes the item scales (and potentially the validity of the survey).	
21	Revision – clarification on “classes” to “courses” (language issue)	
22	[extra item – see question 16]	
23	Unchanged (apart from global “fraternity” deletion, as above) Revision – clarification on “civic” to “community” (language issue)	
24	Unchanged	
25	Unchanged Revision – change “spring” to “fall” – some concern regarding the meaning of the question (course load / work load) but did not change the terms	
26	Unchanged Did not revise “workload” (not sure if this is a language issue or a difficulty issue)	
27	Unchanged Did not revise “reasonable” – could not find a useful alternative (language / cultural issue. It was thought that it was a good thing – a positive thing - to have “reasonable” stress.)	

28	Unchanged Revision – clarification on “university education” and finances to “living during university education” (cultural issue)	
29	Swedish higher education is free (there are no tuition fees). Changed “How do you meet your university expenses (e.g. books, living expenses)?”	“How do you meet your university expenses?”
30	Revision “practicing” to “working” (language / cultural issue)	
31	Revision “practicing” to “working” (language / cultural issue)	
32	Revision “intern” to “intern (praktikant)” (cultural / language issue)	
33	Revision – clarification on “preparing for class” to “preparing for courses” and “spouse” to “partner” (language / cultural issue)	
34	Changed to “university”	“collegiate”
35	Unchanged	
36	Unchanged	
37	Unchanged	
38	Unchanged	
39	Unchanged	
40	Unchanged	
41	Revision – “practicing” to “working” (language / culture issue) Revision – clarification on “global” and “societal contexts” to “global” and “societal context issues” (culture / language issues)	
42	Unchanged	
	Deleted. Inappropriate in Swedish context	“Please indicate your ethnic background: (Mark all that apply) • White/Caucasian • African American/Black • American Indian/Alaska Native • Asian American/Asian • Native Hawaiian/Pacific Islander • Mexican American/Chicano • Puerto Rican • Other Latino • Other”

<table>
<tr><td>43</td><td>Changed:
Swedish native
Swedish citizen
Permanent resident (permanent uppehållstillstånd)
International student from ____ (added)
None of the above
Revision – “Citizenship status” to “status”

Major cultural issues regarding designations that would be important foci of study. High level of international students.</td><td>U.S. Resident
Permanent resident (Green card)
Neither</td></tr>
<tr><td>44</td><td colspan="2">Addition – “if you are an international student please specify your nationality”</td></tr>
<tr><td>45</td><td colspan="2">Revision – clarification on “siblings” to “brother(s) or sister(s)” (language issue)</td></tr>
<tr><td>46</td><td>Changed to equivalent Swedish educational levels. There is no equivalent for “Associate Degree” so item 38678 deleted.
Did not finish gymnasiet
Graduated from gymnasiet (tog studenten)
Attended högskola/universitet but did not complete degree
Completed a kandidatexamen
Completed a magisterexamen
Completed a civilingenjörexamen (described as most Pre-PhD level)
Completed a doktorsexamen</td><td>Did not finish high school
Graduated from high school
Attended university but did not complete degree
Completed an Associate's degree (A.A., A.S., etc.)
Completed a Bachelor's degree (B.A., B.S., etc.)
Completed a Master's degree (M.A., M.S., etc.)
Completed a Professional degree (J.D., M.D., etc.)
Completed a Doctoral degree (Ph.D., Ed.D</td></tr>
<tr><td>47</td><td colspan="2">As question 46, above</td></tr>
<tr><td>48</td><td colspan="2">US dollars converted to Swedish Kroner, and then based on monthly salary vs. yearly (cultural issue). Roughly this worked out to dividing the original numbers by 10 so that the values were whole numbers.</td></tr>
</table>

Appendix C: Concept map protocol

Introductory Statement

We are interested in understanding students' attitudes about, and understanding of, "engineering". We are interested in learning about your perspective.

We will be using a tool called an "Explanogram" to record your thoughts. We will show you how to use it, give you an introductory task to help you get familiar with the tool, and then give you a task to complete. The entire activity should take approximately 30-40 minutes to complete.

Engineering Concepts Task

Instructions: Your goal is to organize the concepts in the list below into a map that represents your beliefs and perceptions about "engineering". There are no right or wrong answers.

Read through the list of concepts below

Use the "explanogram" pen to arrange **ALL** the concepts into an organization of relationships that makes sense for you

Draw and label links between concepts

Check that you have used all the terms

There is no right or wrong way to arrange the concepts. There could be many organizations – we are interested in your perspective.

Analysis	Communication	Complexity
Design	Economics	Environment
Engineering	Ethics	Experimentation
Impact	Implementation	Innovation
International	Judgement	Mathematics
Modelling	Multidisciplinary	Research
Safety	Science	Society
Sustainable	Teamwork	Technology
Theory	Uncertainty	

Participant Task Debrief

- Which terms on the list <u>most</u> represent university-level courses you have taken or are currently taking?
- Which terms on the list <u>most</u> represent your educational experiences outside of the classroom (e.g., internships, student clubs)?
- Which terms on the list <u>least</u> represent university-level courses you have taken or are currently taking?
- What was difficult about this task?
- What was easy?

Appendix D

Critical incident: Background

A central design issue for using the critical incident technique is creating the initial "framing" questions (Flanagan, 1954). A preliminary interview protocol was designed and piloted with 3 academic and postgraduate staff, in two institutions. The initial framing questions were drawn directly from Flanagan (Flanagan, 1954) and were found to be very difficult for participants to interpret. The questions were adapted, firstly to include the word "real" and secondly to prompt the participant to think of concrete examples of engineering activity. These were piloted with 3 further postgraduates and 2 graduate students, and found to be easier for participants to understand.

Critical incident: Interview Protocol

We are making a study of students' attitudes to, and understanding of, "engineering". We believe you are well-qualified to talk to us about <insert subject studied>. The purpose is to get your perceptions and your experiences. There are no right or wrong or desirable or undesirable answers. I would like you to feel comfortable with saying what you really think and how you really feel. The entire interview should take approximately 30 minutes to complete.

Request for General Aim

Q1 In a few words, what would you say real engineering is?

Q2 Can you give me some examples of engineering in the world? (If the participant asks "what is in the world" encourage them to interpret it as they see fit.)

Eliciting Critical Incident

Q3 Can you think of an engineering experience you have had that you particularly enjoyed? Or an experience that you felt represented your ideas of engineering? We are interested in something that actually happened to you.

a. Can you give a brief overview of the experience?

b. What did that experience involve? (Questions i-v are optional prompts)

- i) Scale: was it a big thing? Or a more private, "aha" moment?
- ii) Setting: where did this happen? Was it at home, or in school, or somewhere else?
- iii) Circumstances: was this one in a sequence of things, or a one-off? Were they doing something normal, or unusual?
- iv) Client: was it when you were involved in an engineering experience yourself? If so, whom were you working for?
- v) Groups involved: were you working with others at the time? Were you in a team? Were you working with other teams?

c. What is it about that experience that summarises "engineering"?

d. Why do you think this particular experience came to mind? Why was it important?

Photo elicitation: Background

For this study, participants were shown three images and asked to describe the associations they have with the images regarding "engineering". Our decision to use images was influenced by the Draw-An-Engineer Task (DAET) conducted with pre-university students (Cunningham et al., 2005). We rejected the use of it as a component in this study because we believed that perceptions of drawing ability, and inhibitions over lack of draughtsmanship skills would prejudice our older study population.

Images were piloted over several iterations, across a total of 10 participants. Our selection of images was guided by the principles in Harper (Harper, 2002) that presenting familiar images leads to superficial recognition, but little further insight. We tested—and rejected—several images of engineering classrooms, which simply elicited the response "They're learning engineering". Following Harper, we then selected an historical image, an image of low-tech engineering, and an image of high-tech engineering. These were piloted and found to have the desired "frame breaking" effect (that is, they stimulated participants thinking about "engineering" beyond their initial thoughts and expectations). In testing the order in which images were presented, the best results from were obtained when the "low tech" image was placed between the other two.

Photo elicitation: Interview Protocol

Thank you. I'm going to show you some photographs now.

Q4 *What associations of "engineering" does image <insert image identifier> have for you?*

Start with A, and repeat with subsequent two images. Leave the images on the table. If the participant refers back to a previous image, or makes a comparison between two, make sure to verbally ID the ones they are referring to, either by content "that's the bicycle" or by identifier "image A".

Q5. *After everything we've talked about, what would you say "engineering" is, for you?*

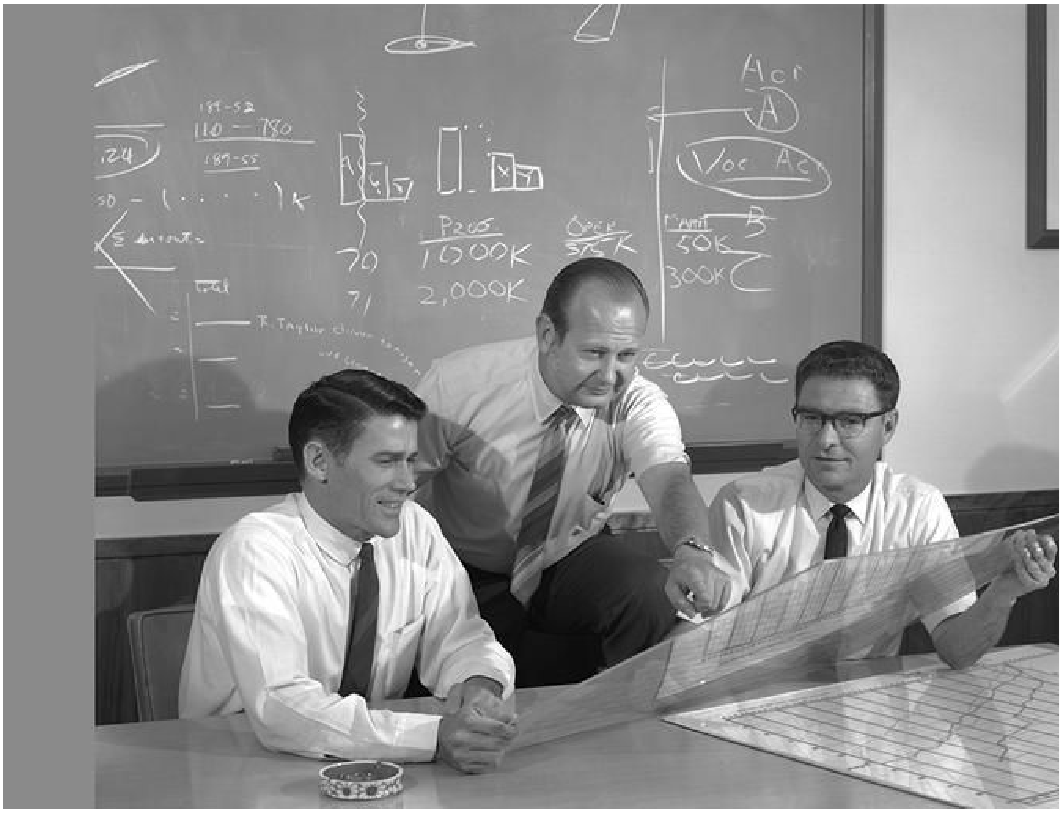
Q6. *Do you think that your views on what engineering is have changed over time?*

- *If so, in what way?*
- *If not, why do you think this is?*

Q7. *Can you think of a specific time or issue that challenged your view of what "engineering" is?*

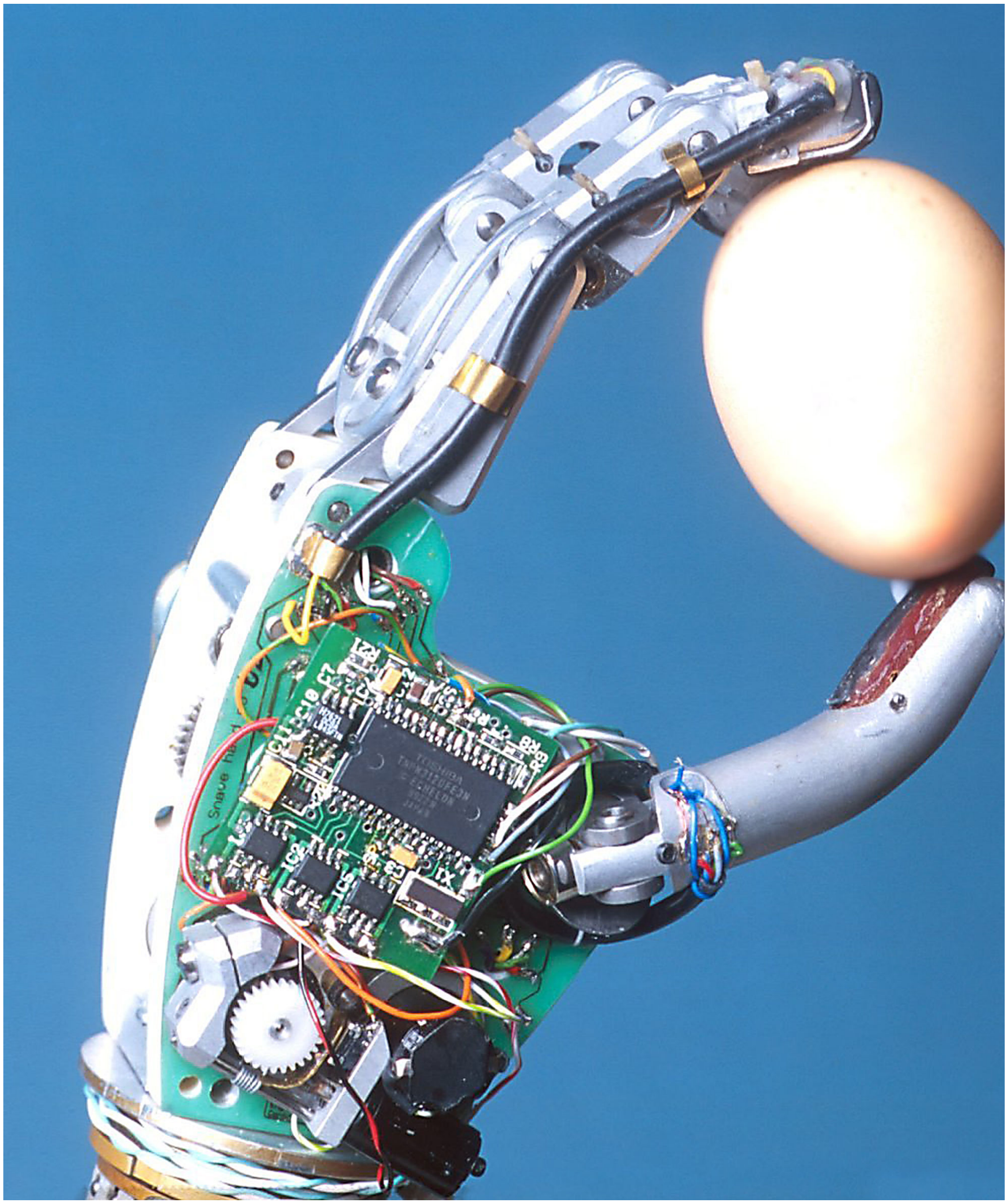
Q8. *Is there anything you would like to add?*

Appendix E: Image Set



A

B



C

Appendix F: APS PIE Constructs in Stepping Stones Survey

Note: APS research team set a target of .70 for Cronbach alphas, although .60 and higher are considered acceptable levels of internal consistency.

Columns represent: Construct number, construct name, question number in Stepping Stones survey, Stepping Stones survey question, as asked.

1a	Academic persistence	7	Do you intend to complete your engineering degree?
1b	Professional persistence	9	Do you intend to work as an engineer, conduct research in engineering, or teach engineering for at least 3 years after graduation?
2a	Motivation (financial)	10	Engineers make more money than most other professionals Engineers are well paid An engineering degree will guarantee me a job when I graduate
2b	Motivation (family influence)	10	My parent(s) would disapprove if I chose a degree other than engineering My parent(s) want me to be an engineer
2c	Motivation (social good)	10	Technology plays an important role in solving society's problems Engineers have contributed greatly to fixing problems in the world
2d	Motivation (high school teacher/mentor influence)	Item not included in Stepping Stones survey	
2e	Motivation (mentor influence)	10	A person working at/from a university has encouraged and/or inspired me to study engineering A non-university affiliated mentor has encouraged and/or inspired me to study engineering
3a	Confidence in math and science skills		Math ability Science (naturvetenskap) ability Ability to apply math and science principles in solving real world problems
3b	Confidence in professional and interpersonal skills	12	Self confidence (social) Leadership ability Public speaking ability Communication skills

			Business ability Ability to perform in teams
3c	Confidence in solving open-ended problems	12	Critical thinking skills
4a	Perceived importance of math and science skills	13	Math ability Science (naturvetenskap) ability Ability to apply math and science principles in solving real world problems
4b	Perceived importance of professional and interpersonal skills	13	Self confidence (social) Leadership ability Public speaking ability Communication skills Business ability Ability to perform in teams
5	Knowledge of the engineering profession.	11	I am familiar with what a practicing engineer does
6a	Exposure to project-based learning methods (individual projects)	Individual and group project-based learning was not distinguished in the Stepping Stones survey	
6b	Exposure to project-based learning methods (team projects)		
7	Collaborative work style	11	I prefer studying in a group to studying by myself I prefer working as part of a team to working alone I get along well with others in study situations I am a collaborative person
8	Extra-curricular fulfilment	23, 24	Some people are involved in non-engineering activities on or off campus, such as hobbies, community or church organizations, campus publications, student government, sports, etc. How important is it for you to be involved in these kinds of activities? How often are you involved in the kinds of non-engineering activities described above?
9	Curriculum overload	25	Thinking about your university experience since the beginning of the Fall term, please indicate how much pressure you are feeling related to the

			following: Course load (amount of course material being covered) Course pace (the speed at which the course material is being covered) Balance between social and academic life
		27	How stressed do you feel in your coursework right now?
10	Financial difficulties	28	Do you have any concern about your ability to finance your living during your university education?
11a	Academic disengagement (liberal arts courses)	18	Came late to elective class Skipped elective class Turned in elective assignments that did not reflect your best work Turned in elective assignments late
11b	Academic disengagement (engineering related)	17	Came late to engineering class Skipped engineering class Turned in engineering assignments that did not reflect your best work Turned in engineering assignments late
11c	Academic disengagement (overall)	17, 18	Came late to elective class Skipped elective class Turned in elective assignments that did not reflect your best work Turned in elective assignments late Came late to engineering class Skipped engineering class Turned in engineering assignments that did not reflect your best work Turned in engineering assignments late
12	Frequency of interaction with instructors	19	Lecturing staff (lärare) during visiting hours Lecturing staff (lärare) outside of class or visiting hours Teaching Assistants (handledare) during class Teaching Assistants (handledare) during visiting hours Teaching Assistants (handledare) outside of class or visiting hours

13a	Satisfaction with instructors	14	Quality of instruction by lecturing staff (lärare) Quality of advising by lecturing staff (lärare) Availability of lecturing staff (lärare) Quality of instruction by teaching assistants (handledare) Quality of advising by teaching assistants (handledare) Availability of teaching assistants (handledare)
13b	Satisfaction with academic facilities	15	Computer facilities Libraries Classrooms Laboratories
13c	Overall satisfaction with collegiate experience	34	Please rate the overall quality of your university experience so far:

Appendix G: Construct Analysis

All statistics were computed using R software for statistical computing. (Information regarding this software is available at http://www.r-project.org/). In the Cronbach alpha analysis items, some items had a high level of responses of "not applicable". These responses were removed (see "# with NA excluded" column in table G1, below). In most of these situations, the Cronbach alpha computed was significantly greater when "NA" was included, potentially over exaggerating the accuracy of the analysis. Therefore, for this study we chose the most conservative values – those derived from excluding "NA" responses. Three constructs (highlighted in the table below) were not computed due to lack of data. Construct 2d was not included because there was only one item associated with the construct. Constructs 6a and 6b were not included because of an error in the survey. Construct 10 was not included because it was not considered to be useful for the Swedish context.

Table G1: Analysis of Constructs

Construct	Construct Name	Cronbach Alpha	with N/A	# with NA excluded
1a	Academic persistence	-		
1b	Professional persistence	-		
2a	Motivation (financial)	0.731		
2b	Motivation (family influence)	0.776		
2c	Motivation (social good)	0.616		
2d	Motivation (high school teacher/mentor influence)	Not measured		
2e	Motivation (mentor influence)	0.507		
3a	Confidence in math and science skills	0.743		
3b	Confidence in professional and interpersonal skills	0.785		
3c	Confidence in solving open-ended problems	-		
4a	Perceived importance of math and science skills	0.744		
4b	Perceived importance of professional and interpersonal skills	0.743		
5	Knowledge of the engineering profession.	Non-numeric factors		
6a	Exposure to project-based learning methods (individual projects)	Not measured		
6b	Exposure to project-based learning methods (team projects)	Not measured		
7	Collaborative work style	0.715		
8	Extra-curricular fulfillment			
9	Curriculum overload	0.728	5	
10	Financial difficulties			
11a	Academic disengagement (liberal arts courses	0.646	0.948	
11b	Academic disengagement (engineering related)	0.604	0.603	487
11c	Academic disengagement (overall)	0.790		323
12	Frequency of interaction with instructors	0.750		
13a	Satisfaction with instructors	0.830	0.837	434
13b	Satisfaction with academic facilities	0.629	0.387	319
13c	Overall satisfaction with collegiate experience	-		

Table G2: Calculation of Constructs

Construct	Construct Name	SS Survey elements					
1a	Academic persistence	X7					
1b	Professional persistence	X9					
2a	Motivation (financial)	X10_2	X10_5	X10_8			
2b	Motivation (family influence)	X10_3	X10_7				
2c	Motivation (social good)	X10_1	X10_4				
2d	Motivation (high school teacher/mentor influence)						
2e	Motivation (mentor influence)	X10_10	X10_11				
3a	Confidence in math and science skills	X12_4	X12_5	X12_8			
3b	Confidence in professional and interpersonal skills	X12_1	X12_2	X12_3	X12_7	X12_9	X12_10
3c	Confidence in solving open-ended problems	X12_11					
4a	Perceived importance of math and science skills	X13_4	X13_5	X13_8			
4b	Perceived importance of professional and interpersonal skills	X13_1	X13_2	X13_3	X13_7	X13_9	X13_10
5	Knowledge of the engineering profession.	X11_6	X30	X31	X32		
6a	Exposure to project-based learning methods (individual projects)						
6b	Exposure to project-based learning methods (team projects)						
7	Collaborative work style	X11_1	X11_2	X11_3	X11_4		
8	Extra-curricular fulfillment						
9	Curriculum overload	X25_1	X25_2	X25_3			
10	Financial difficulties						
11a	Academic disengagement (liberal arts courses	X18_1	X18_2	X18_3	X18_4		
11b	Academic disengagement (engineering related)	X17_1	X17_2	X17_3	X17_4		
11c	Academic disengagement (overall)	All o above 17 and 18					
12	Frequency of interaction with instructors	X19_1	X19_2	X19_3	X19_4	X19_5	X19_6
13a	Satisfaction with instructors	X14_1	X14_2	X14_3	X14_4	X14_5	X14_6
13b	Satisfaction with academic facilities	X15_1	X15_2	X15_3	X15_6		
13c	Overall satisfaction with collegiate experience	X34					

Appendix H: Institutional Characterisations

The following information contextualising Swedish higher education is abstracted from *Studying in higher education (Engelska)* (Högskoleverket, 2006):

Eligibility and selection: To study at a Swedish university or university college basic eligibility is required. In addition, for most programs, special eligibility is required. For engineering programs this usually consists of additional knowledge in mathematics, physics, and chemistry. Schools are open to everyone, and about half of the population studies at higher education institutions at some time in their lives. Selection into a program is based on high school grades and a national aptitude test.

Student characteristics: Most students in Swedish higher education are between 20 and 25 years old, however some are older. Men and women are equally represented in higher education. More and more people with a non-Swedish enrol in Swedish higher education programs.

Programs of study: Universities can always offer post-graduate studies: university colleges may offer post-graduate studies in areas of high demand (as deemed by the government). Students may either choose to combine courses into a degree or choose an existing study program. Studies may be part time or full time. Diplomas awarded include: University diploma (120 credits or 2 full time years), Bachelor's degree (180 credits or 3 full time years), Degree of Masters (240 credits or 4 full time years), and Master's Degree (300 credits or 5 full time years). The academic year is broken into two terms.

School finances: Swedish higher education institutions do not charge term fees (tuition) – education is paid for by the state. However students will need money for basic needs as well as course materials and books. Financial aid (in the form of student loans) is available up to a fixed amount for a fixed period of time.

The following information is provided as background on the institutions (Swedish universities and university colleges) included in this study.

Institution B is a university in a middle sized town in Sweden. The students are mostly recruited from the local region. There are over 7,000 students, mostly in three year bachelor study programmes that span many different subjects such as health care, social sciences, humanities, teacher education, media, mathematics, natural sciences and engineering. The engineering program offers different engineering disciplines, including: civil engineering, environment, mechanics and materials, electronics and computer engineering, logistics and industrial economy, and land survey engineering. There are about 300 engineering students. The institution offers some master programmes, but there is no regular graduate education at this university and in most cases, graduate students are connected to other universities.

Institution C is a large university with research and education in all disciplines. It is organised into several faculties, college and research centres. The faculty of science and engineering has over 5,000 students in a wide range of study programs, ranging from 3-years programs to PhD programs. Currently (2007), the faculty offers six different Master of Science programmes in Engineering, six Bachelor of Science programmes in Engineering and three different vocational programmes. The yearly intake to these programs has dropped considerably during the last few years and ranges currently from about ten to about 60 (in Computer Science).

Institution D is a university with over 20,000 undergraduate students, 1,000 research students and 3,500 employees of which 300 are professors. The institution is divided into four faculties, and the technical faculty has 9,500 undergraduate students, equivalent to 6,100 full time students. Most of these (88%) are enrolled in one of the many programs. Of the Swedish students, 30% come from the region and 70% from other parts of the country. In the technical faculty about 25% of the students are female. Degrees awarded include Master of Science in Engineering (e.g., applied physics in electrical engineering, industrial engineering and management, information technology, communication and transportation, design and product development, engineering biology, and mechanical engineering), 2 year programs in such areas as computer science and engineering mechanics, and Bachelor of Science in Engineering and in Mathematics, Computer Science or Natural Science, and International Master of Science programs.

Institution E has two campuses with approximately 15,000 students and over 1,000 employees. They offer 40 undergraduate programs, 40 graduate programs and approximately 500 courses. Institution E has established research areas in engineering and technology, natural science, humanities, social science and health science. Half of the students are studying engineering or natural science and the other half are enrolled in social science, behavioural science, humanities or health science. Since 2000 this institution has the right to educate and examine researchers within the scientific area of technology, which has lead to new doctoral students. Students from this institution are in demand on national and international labour markets by being well educated and innovative critical thinkers.

Institution F is a comprehensive international research university dedicated to advancing science, scholarship, and higher education. The Faculty of Science and Technology has over 200 professors. There are 10,000 undergraduate students distributed among nine Master of Science programmes in engineering, nine Bachelor of Science programmes, and nine Master of Science programmes. Annually 136 doctoral degrees are produced.

Data for this study was collected from a subset of students at this institution. This department offers a wide range of programs for undergraduate study and enrols more than 3500 students per year in programs around theoretical computing science, human-computer interaction, and computational and control engineering. The Information Technology Program leads to a master's degree in engineering after four and a half years. There is also a 4 year program that leads to a master of science in computer science. The department also offers a master's level program that focuses on how technology functions in society. The department also offers independent courses during term, via distance learning, or in the summer, as well as Net-based courses. Offerings include both descriptive courses at the beginner level and specialist courses.

Institution H offers programs in engineering devoted to the academic subjects of software engineering, computer science, computer engineering, signal processing, mechanics, telecommunications and industrial management and economics. In some of the subjects, there are various specialisations (or applications). For example, Institution H has programmes in security engineering and game development within the subject of computer science. Usually, the entrance requirements for students to join the educational programmes are "general eligibility" with a passing grade in all courses, however there are some exceptions. Typically, the age range of students varies from 19 to 36 years of age. The range of engineering degrees offered are 3+2 year programmes across the disciplines of civil engineering, master of science, and bachelor of science for the various subjects mentioned above. Enrolment is around 15-20 students per year, for the civil engineering- and Bachelor of Science programmes whereas enrolment for the Master programme may be as high as 50 students per year.

Institution I is a large technical university in Sweden which has programs that focus on Information and Communication Technology. Activities span the entire field of information technology in its widest sense. Research is predominantly in the fields of nanoelectronics, photonics, electronics and computer systems, software technology, communication and cognitive sciences. Study programmes available include: Master of Science in Information and Communication Technology 5 year programme, Master of Science in Microelectronics 5 year programme, Bachelor of Science in Computer Engineering 3 year programme, Bachelor of Science in Business Engineering 3 year programme, and Bachelor of Science Information and Communication Technology 3 year programme. There are also several two year international master programmes that mainly recruit from countries other than Sweden. The number of Masters students is over 500 while the number of Bachelor students is closer to 600. Around 800 students are enrolled in the International Masters programmes. There are approximately 300 employees, 25 professors and over 220 graduate students.

Institution K is a relatively large university in which most students come from outside of the local area. Entrance requirements for 5 and 4.5 year engineering degrees are FyB, ChA, and MaD. For 3 year engineering degrees the requirement is generally at least MaD. There are many program options for students. Some programs start together and separate after 1, 2 or 3 years. Also, students can postpone their choice of program until the programs separate. Currently there are eight 4.5 and 5 year programs, and eight 3 year programs. Enrolments for 2006 indicate approximately 150 students in the longer degree programs and 400 in the shorter degree program

Appendix I: Categories for coding programs of study / disciplines

In order to enable internal comparisons by discipline across study instruments, such as responses to the survey and background data, a set of disciplinary categories was derived.

1. Aerospace engineering and mechanics
2. Bio-inspired and agricultural engineering
3. Biomedical engineering
4. Chemical engineering (and chemistry)
5. Civil engineering (väg och vatten)
6. Computer engineering
7. Computer Science
8. Electrical engineering (and micro-electronics)
9. Geological engineering
10. Information technology
11. Materials science and engineering
12. Mathematics
13. Mechanical engineering
14. Interaction design
15. Software engineering
16. Physics (and technical physics)
17. Systems in Technology and Society
18. Energy engineering
19. Industrial economics
20. Construction engineering
21. Other (less than 5 respondents in total)
    a. "Other" (from the survey data compilation)
    b. Cognitive science
    c. Transport and logistics

Appendix J: Concept Map Debrief (internal analysis)

When considering students' perceptions of engineering, one perspective to explore is how students associate broad engineering concepts to their experiences in university courses. This kind of analysis may help explain the kinds of concepts students associate or don't associate with engineering. For example, if students consider "design" to be a central engineering concept one explanation may be related to the extent to which they have had design experiences. Additional insights into the influence of an engineering education may be gained by comparing first year and graduating students' perceptions of engineering concepts in relation to their course work. This kind of comparison assumes that graduating students have completed more courses and, as such, have more experiences on which they can draw. Finally, including information on the kinds of engineering concepts university instructors most associate with university courses adds another perspective for a richer analysis.

In this preliminary study, the research question is "what broad engineering concepts do engineering students and educators most associate with university courses?" Data was collected by asking participants who completed the concept map task described earlier to complete a debrief protocol. The first question on the debrief sheet (of 5 questions total) is the focus of this analysis: *Which terms on the list most represent university-level courses you have taken or are currently taking?* Responses to this question were placed in a spreadsheet and then uploaded into a database program. This database included the subject identifier code, an institution code, an experience code (F=first year, G=graduating student, E=educator, and A=alumni), and a list of terms based on the original concept map task (see table below).

Table J1: List of terms in concept map debrief

analysis	ethics	mathematics	sustainable
communication	experimentation	modelling	teamwork
complexity	impact	multidisciplinary	technology
Design	implementation	research	theory
economics	innovation	safety	uncertainty
engineering	international	science	
environment	judgment	society	

A final tabulation regarding total number of participants is provided in the table below. In particular, three participants who completed the concept map task did not complete the debrief sheet, and another 4 were removed because they did not use the list terms in the table above. Participants who did not provide any responses to this question are not included in this analysis. Also, the alumnus was not included in this analysis.

Table J2: Number of participants by school and experience level

Institution	Educator (E)	First Year (F)	Graduating Year (G)	Alumni (A)	Total
B	2	6	5	0	13
C	4	7	9	1	21
D	2	5	6	0	13
E	2	4	4	0	10
F	2	5	3	0	10
H	4	9	9	0	22
I	2	6	5	0	13
K	1	2	2	0	5
	19	44	43	1	107

Results

All results were calculated using a cross-tab query program in the database.

Table J3: An institutional comparison for participants' association of engineering concepts with university courses (ranked from total most represented to least).

INSTITUTION	B	C	D	E	F	H	I	K	TOTAL
mathematics	71%	36%	85%	60%	75%	50%	85%	100%	68%
analysis	36%	55%	62%	50%	50%	41%	31%	80%	51%
theory	36%	36%	31%	60%	50%	41%	54%	80%	47%
teamwork	29%	41%	69%	30%	50%	32%	8%	60%	40%
technology	29%	36%	38%	30%	33%	18%	38%	60%	35%
implementation	21%	45%	38%	30%	8%	41%	15%	40%	34%
experiment	29%	23%	38%	20%	17%	36%	31%	60%	32%
engineering	29%	32%	8%	40%	25%	23%	23%	80%	30%
modelling	21%	27%	31%	30%	33%	14%	8%	40%	25%
science	7%	14%	15%	20%	25%	23%	38%	60%	23%
design	21%	27%	31%	30%	8%	9%	0%	40%	20%
communication	14%	14%	23%	20%	42%	14%	8%	20%	19%
research	21%	9%	8%	30%	25%	5%	8%	40%	15%
complexity	0%	9%	23%	20%	50%	5%	8%	0%	14%
innovation	7%	5%	0%	20%	17%	18%	0%	20%	11%
economics	0%	0%	15%	10%	25%	9%	8%	20%	10%
international	0%	5%	23%	20%	8%	0%	15%	20%	10%
uncertainty	0%	0%	15%	20%	33%	9%	0%	0%	9%
multidisciplinary	0%	5%	15%	10%	17%	0%	0%	20%	7%
safety	0%	0%	0%	10%	8%	14%	0%	20%	6%
ethics	0%	0%	0%	20%	8%	5%	0%	20%	5%
judgment	14%	0%	0%	10%	8%	5%	0%	0%	5%
society	0%	0%	0%	0%	33%	0%	0%	20%	4%
environment	7%	0%	0%	0%	8%	0%	0%	20%	3%
impact	0%	0%	0%	10%	8%	5%	0%	0%	3%
sustainable	7%	0%	0%	0%	8%	5%	0%	0%	3%

Across all institutions, participants strongly associate concepts such as mathematics, analysis, theory, teamwork, technology, and implementation with university courses. They are less likely to associate university courses with such concepts such as innovation, economics, multidisciplinary, ethics, judgment, society, environment, impact and sustainability. Many of these concepts are highlighted in documents on improving Swedish engineering education (e.g., Maury, 2004). For many of these concepts, there are institutional differences (see Figure J1). For example, participants associated with institutions F and K are more likely to associate the concepts of society and environment with university courses. Participants associated with institutions E, F, and H associate the concepts of impact and sustainability with university courses.

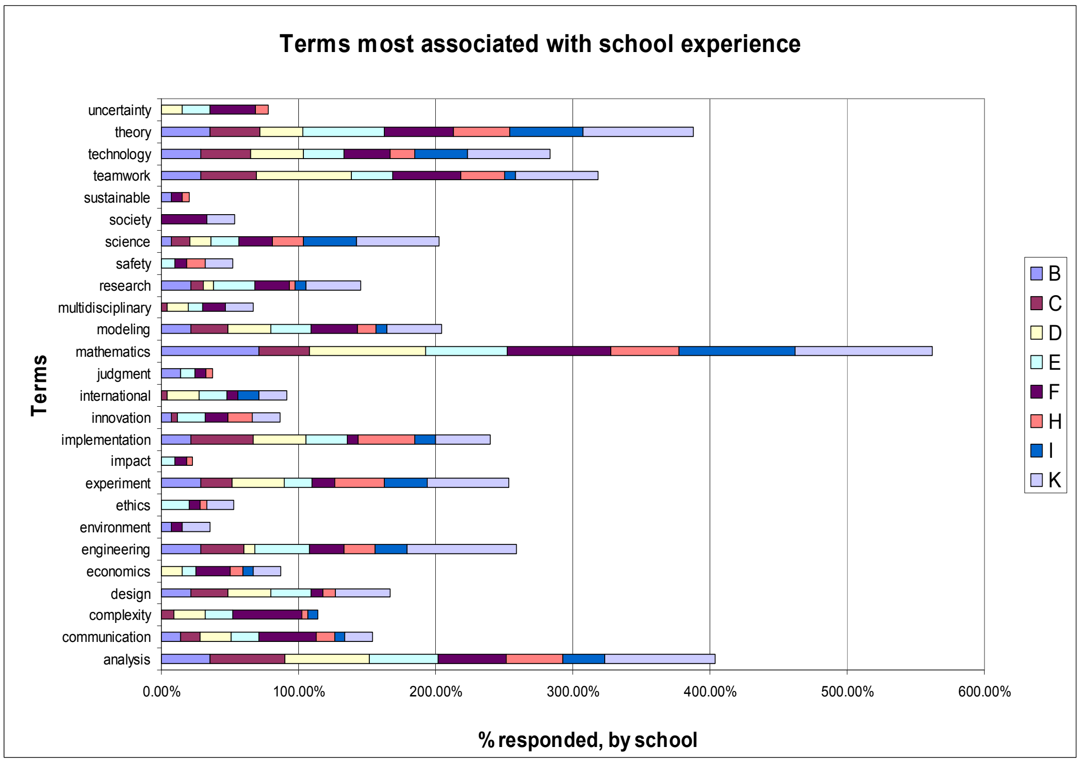


Figure J1: A comparison of associations between engineering concepts and university courses across institutions.

When comparing across experience levels (see Table J4 below), interesting differences emerge. First year students, graduating students, and educators were similar in their responses to some of the engineering concepts (see shaded rows in Table J4). For example, all groups had some associations regarding communication and research with their university education. All groups had far fewer associations with the concepts of environment, judgment, and ethics.

“Mathematics” was a concept that was strongly associated with university courses across all institutions; however the experience level comparisons illustrate a declining relationship regarding the prevalence of mathematics in university courses. 77% of the first year students, 59% of the graduating students, and only half of the educators associated mathematics with their university courses. “Science” associations with university courses also varied across groups: 20% of first year, 11% of graduating students, and half of the educators.

Finally, many of the concepts most associated with university courses paint a picture of university courses as focusing on analytical aspects of engineering more than design aspects. Similarly, for those concepts in Table J4 that represent the context of engineering activities (e.g., social, environmental), or that represent engineering as an innovative activity, students were more likely than educators to associate these ideas with university courses.

Table J4: Experience level comparison–association of concepts with university courses

Group	Educator (E) (N=20)	First year (F) (N=44)	Graduating year (G) (N=46)
analysis	9	24	20
communication	6	7	7
complexity	1	4	10
design	4	9	8
economics	1	5	4
engineering	5	13	13
environment	0	2	1
ethics	1	2	2
experiment	6	14	13
impact	1	1	1
implementation	5	13	17
innovation	0	4	7
international	0	6	4
judgment	2	1	2
mathematics	10	34	27
modelling	5	10	11
multidisciplinary	0	2	5
research	5	5	6
safety	0	2	4
science	10	9	5
society	0	3	2
sustainable	0	3	0
teamwork	5	20	17
technology	5	15	16
theory	8	20	21
uncertainty	2	2	6
total by group	20	44	46

Recent technical reports from the Department of Information Technology

2007-017 Olof Rensfelt and Lars-Åke Larzon: *A Bandwidth Study of a DHT in a Heterogeneous Environment*

2007-016 Erik Nordström, Per Gunningberg, Christian Rohner, and Oskar Wibling: *A Cross-Environment Study of Routing Protocols for Wireless Multi-hop Networks*

2007-015 Torbjörn Wigren: *MATLAB Software for Recursive Identification of Systems With Output Quantization Revision 1*

2007-014 Parosh Aziz Abdulla, Giorgio Delzanno, and Ahmed Rezine: *Parameterized Verification of Infinite-state Processes with Global Conditions*

2007-013 Torbjörn Wigren and Linda Brus: *MATLAB Software for Recursive Identification and Scaling Using a Structured Nonlinear Black-box Model - Revision 3*

2007-012 Alexander Churilov, Alexander Medvedev, and Alexander Shepeljavyi: *Mathematical Model of Non-Basal Testosterone Regulation in the Male by Pulse Modulated Feedback*

2007-011 Lars Ferm, Per Lötstedt, and Andreas Hellander: *A Hierarchy of Approximations of the Master Equation Scaled by a Size Parameter*

2007-010 Torbjörn Wigren: *MATLAB software for Recursive Identification of Wiener Systems - Revision 2*

2007-009 Magnus Ågren, Pierre Flener, and Justin Pearson: *On Constraint-Oriented Neighbours for Local Search*

2007-008 Erik Bängtsson and Maya Neytcheva: *Finite Element Block-Factorized Preconditioners*

2007-007 Malin Ljungberg: *Composable Difference Operators for Coordinate Invariant Partial Differential Equations*

2007-006 Anders Berglund and Mattias Wiggberg (eds.): *Proceedings from the 6th Baltic Sea Conference in Computing Education Research, Koli Calling*

2007-005 Parosh Aziz Abdulla, Noomene Ben Henda, Richard Mayr, Sven Sandberg, and Luca de Alfaro: *Stochastic Games with Lossy Channels*

2007-004 Jonas Persson: *Pricing American Options Using a Space-time Adaptive Finite Difference Method*

2007-003 Pierre Flener, Justin Pearson, Magnus Ågren, Carlos Garcia Avello, and Mete Çeliktin: *Air-Traffic Complexity Resolution in Multi-Sector Planning*

2007-002 Jing Gong and Jan Nordström: *A Stable and Efficient Hybrid Scheme for Viscous Problems in Complex Geometries*

2006-052 Parosh Aziz Abdulla, Noomene Ben Henda, Giorgio Delzanno, and Ahmed Rezine: *Regular Model Checking without Transducers (On Efficient Verification of Parameterized Systems)*

2006-051 Erik Bängtsson and Björn Lund: *A Comparison Between Two Solution Techniques to Solve the Equations of Linear Isostasy*

2006-050 Iordanis Kavathatzopoulos: *AvI-enkäten: Ett verktyg för att mäta användbarhet, stress och nytta av IT-stöd*

2006-049 Stefan Blomkvist: *The User as a Personality: A Reflection on the Theoretical and Practical Use of Personas in HCI Design*

UPPSALA UNIVERSITET

June 2007
ISSN 1404-3203
http://www.it.uu.se/