International Journal of Engineering Education Vol. 29, No. 3, pp. 698–713, 2013
Printed in Great Britain

0949-149X/91 $3.00+0.00

What Does It Take to Become a Good Engineer? Identifying Cross-National Engineering Student Profiles According to Perceived Importance of Skills*

S. HAASE
Centre for Studies in Research and Research Policy, Business and Social Sciences, Aarhus University, Bartholins Allé 7, 8000 Aarhus C, Denmark. E-mail: sh@cfa.au.dk

H. L. CHEN
Department of Mechanical Engineering, School of Engineering, Stanford University, Wallenberg Hall, 450 Serra Mall, Bldg. 160, Stanford, CA, 94305-2055 USA.

S. SHEPPARD
Department of Mechanical Engineering, School of Engineering, Stanford University, Peterson Building (550), Room 119, Stanford, CA, 94305-4021 USA.

A. KOLMOS
Development and Planning, Aalborg University, Vestre Havnepromenade 5, 9000 Aalborg, Denmark.

N. MEJLGAARD
Centre for Studies in Research and Research Policy, Business and Social Sciences, Aarhus University, Bartholins Allé 7, 8000 Aarhus C, Denmark.

Engineers of the future are expected to possess a range of competencies in addition to math and science skills. This paper turns to engineering students to explore what they think it takes to become a good engineer. Profiles are identified by means of a large-scale survey-based investigation of the perceptions of first year engineering students in the US and in Denmark with respect to the importance of math/science skills and interpersonal and professional skills for successful engineering. Four groups of first year engineering students are defined according to combinations of high and low importance assessments of each of the two skill types in both countries. This leads to analytically derived groups emphasizing math/science skills, interpersonal and professional skills, both skill types, and none of the skills. Differences and similarities between these groups are explored in terms of relative group sizes and gender composition, levels of confidence, and motivation to study engineering. The findings show that the four engineering student groups have distinct profiles with different characteristics in terms of motivation and confidence and which may each require different educational approaches to become broad thinking engineers. Apart from the exploratory investigation of group differences within each country, the paper also examines whether the four group profiles are nationally confined or if common tendencies shared by engineering students in both countries exist. The paper contributes to the literature on engineering education and serves to inform engineering educators and institutions worldwide with new insights into the expectations and perceptions of actual students who are at the very beginning of their pathway to an engineering education.

Keywords: engineering skills; broad thinking, engineering education research; comparative survey analysis

1. Introduction

Engineers are no longer singularly required to have expertise in a specific technical skill area. Technologies are changing and the boundaries in and between science and technology disciplines are blurring. Future engineers will have to be able to transcend disciplinary limitations, work in different fields, and master communication and intercultural collaboration skills. Furthermore, the need for contextual sensitivity and responsiveness, the ability to consider economic, environmental, and social sustainability as well as political, legal, and ethical questions in problem interpretation and problem solving processes are required in order to address new challenges to human civilization. Even though a historic tension between technical and contextual focus still exists in varying degrees among engineering faculty members and in the ongoing struggle to design engineering curricula [1], engineering education researchers agree to a large extent that these broad thinking skills and abilities are pivotal competencies of successful engineers of the future [cf. 1–11].

This paper focuses on two types of engineering skills, namely interpersonal and professional skills (IPP skills) and math/science skills (M/S skills), as well as the interplay between them. A combination of both types of skills into a double focus or a broader kind of thinking is generally considered to be highly desirable [1, 3–5, 9, 11–31].

Although the Danish and the US engineering education systems are aligned in their shared goal

* Accepted 26 January 2013.

to provide highly skilled engineers of the future, the two systems are not directly comparable. Economic and cultural differences influence the design of these engineering education systems and the engineering students within them. One obvious difference is found when comparing the sizes and international presence of these two nations. The Danish economic and educational structures are also qualitatively different from those in the United States. As with most other higher education institutions in Denmark, engineering education is considered a public good, and Danish youths are encouraged to engage in higher education due to the cost–benefit values of education for society, among other things [32]. As a result, students do not pay fees to pursue an engineering degree in Denmark.

Traditionally, the nature of the Danish welfare system would have made financial motivations to pursue higher education somewhat less important to Danes than to Americans because poverty has been almost non-existent in Denmark. Over the last decade, however, the gap between the richest and the poorest has grown in Denmark, and the recent global financial crisis has renewed concerns over financial security [33–34], which may reduce the cultural differences in how IPP skills and M/S skills are perceived between the two countries. The timing of the survey administration (the data collection in Denmark took place in 2010, two years after the US survey) suggests that the financial crisis may have a stronger impact on the Danish students than the American engineering students.

1.1 The societal value of interpersonal and professional skills relative to math/science skills

The Danish educational system has a long tradition of emphasizing the humanistic, so-called *Bildung* aspects of supposedly educating citizens with personal integrity and self-dependence as well as teamwork skills, in other words, citizens who are considerate of the democratic values of Danish society. This emphasis should prime Danish students towards relatively high levels of confidence in interpersonal and professional skills as compared with math/science skills. On the other hand, a shift in political values over the last decade, in part due to the results of the Organization for Economic Co-Operation and Development's Program for International Student Assessment (PISA) where the placement of Danish primary school children fell in ranking [35–37], may also have resulted in the changes in primary and secondary school teaching that led to a strengthened focus on math and natural science.

In the US there has been a corresponding interest in fostering the development of "professional" or "soft" skills in addition to technical knowledge and understanding. The 2004 report from the National Academy of Engineering on *The Engineer of 2020* highlighted these areas of knowledge and skills that are necessary in order to address the engineering challenges of the future [38]. In addition, many of these competencies have also been incorporated into the outcomes criteria established by the national accrediting body for engineering programs, ABET [39].

As noted in research studies from the Center for the Study of Higher Education at the Pennsylvania State University [40] and a report from the National Academy of Engineering [38], engineering faculty increasingly recognize the importance of professional and interpersonal skills such as teamwork, problem solving, and critical thinking. Innovations in engineering curricula, teaching approaches, and pedagogical activities both inside and outside the classroom are aimed at contributing to a more holistic education that will provide engineering students with a wide range of opportunities to acquire, develop, and practice these professional abilities [41–42].

1.2 The Engineering education systems in the US and in Denmark

Two cross-national studies serve as contexts for the comparison of engineering student approaches to perceived importance of engineering skills. The data collected in the US stem from 21 different universities offering a variety of engineering majors. These students are typically required to complete a series of general education courses covering humanities, literature, science, and math courses before choosing their major during the first two years of their undergraduate education. In addition, students also need to fulfill pre-requisite or introductory courses in their subject of interest or major. The undergraduate bachelor's degree in engineering is generally completed in four to five years.

The Danish engineering education system offers two different types of educational pathways. One is an academic master's level education corresponding to five years of full-time studies at a university; the other is a less academically focused education offered both in universities and at university colleges or engineering colleges lasting $3\frac{1}{2}$ years, including a six month internship that leads to a professional bachelor's degree. In fall 2010, the proportion of students enrolling in academic and professional engineering programs in Denmark was close to equal (45 and 55% respectively).

2. Research focus

This paper focuses on the actual perceptions of the importance of IPP skills and M/S skills for engineering among future engineers themselves. Future engineers' perceived importance of the skills necessary to become successful engineers provides insights into their baseline expectations of what engineering is about and what it will take for them to succeed in engineering. This paper explores what combinations of these two types of skills are required in order to become a good engineer, according to first year engineering students.

Considering that engineering education researchers emphasize the importance of *both* traditional, math/science deeds *and* more interpersonal and professional skills, combinations of high or low importance estimates of both skill types are defined in a quadrant model and are examined for their validity as indicators of distinct differences on a range of other outcome variables in Denmark and in the US. The four groups identified by the model are examined in a comparative manner to assess whether each of the profiles are nationally confined or if common tendencies shared by engineering students in both countries exist.

This research draws upon two large sets of empirical survey data collected from first year engineering students across two nations that are both highly concerned about the future of the engineering profession.

The research focus is summarized in the following research questions:

RQ1: Can knowledge of engineering students' perceptions of the importance of different types of engineering skills represent a valid model of depicting various characteristics of engineering students? Do groups of students with different conceptions of engineering skill importance vary with respect to their confidence in these skills, their motivation to study engineering, and their gender composition?

RQ2: What differences and similarities can be found in the way this model applies to first year engineering students in the US and in Denmark?

The goal of this research is to better inform engineering education systems and teachers who are intent on transforming their respective engineering education systems with insights into the characteristics of their students so that they can more effectively develop well-rounded engineers.

3. Research design

This section describes the two surveys that form the empirical foundation of the analyses and methods. First, the data collection, the respondents and the foci of the national surveys will be portrayed followed by an outline of the statistical analyses. These analyses involve weighting of the response data, the use of factor analysis and factor scores, index construction, and use of ANOVA, Kruskall–Wallis H test, Welch Robust Test of Equality of means and relevant post hoc testing.

3.1 Data presentation

The basis for these analyses is a set of surveys conducted in the US and in Denmark respectively. The Academic Pathways of People Learning Engineering Survey (APPLES) was an online survey deployed in winter 2008 to a stratified sample of 21 universities in the US. APPLES was completed by over 4200 undergraduate engineering students at all levels of academic standing. For more information on the American survey methods and results, see Sheppard et al. [43] and Atman et al. [44].

A nationwide survey of all Danish students commencing an engineering education in fall 2010 deployed a subset of the items initially developed as part of the APPLE Survey, as well as some additional items. This renders possible the comparison of responses across the two countries. After piloting the instrument to test for item interpretation and understanding, the Danish survey was web-administered in the very first month after the students commenced their engineering studies. The survey was administered to all Danish engineering students in the then eight engineering education institutions offering 105 different engineering programs in total.

As relevant groups of comparison, the newly enrolled Danish engineering students were matched with American freshmen who had indicated that engineering was their current or first choice of major. The Danes were somewhat older than the US freshmen, and while they had already decided to pursue a specific engineering program, they were in the first month of their studies. In contrast, the US freshmen responded to the survey in the middle of their first year after having completed more general coursework and few, if any, engineering classes. However, American engineering students in their second or third year, and first year students who reported uncertainty in pursuing an engineering major were excluded in order to ensure reasonable comparability in the Danish and American engineering pathways. Details on these two groups can be found in Table 1.

The APPLES instrument was designed to contribute to the understanding of: (1) how students' engineering knowledge develops and changes over time; (2) what motivates students to study engineering; and (3) how students conceive their engineering future [46, 47]. The Danish study focuses on professional identity and attitudes towards environmental and non-environmental sustainability and societal

Table 1. Overview of the two student groups participating in the surveys

	US first year engineering majors	DK newly enrolled engineering students
Year of data collection	Early 2008	October 2010
Time of survey administration	Middle of first year	First month of their studies
Number of respondents	831	1682[i]
Age[ii]	96% below 20 years of age	22.3 years in average
Gender distribution	F: 36%[iii] M: 64%	F: 24% M: 76%
Engineering program progress	Indicated an engineering major as their current or first choice of major in the survey, may not officially have declared engineering; have taken few, if any, engineering classes	Have chosen engineering as their field, have not taken any engineering classes

i) The Danish survey was nationwide reaching the total population of 3630 engineering freshmen in the country. Only responding students are included in the analyses. Register data including gender were available for the entire population. No severe skewness in gender representation was found between responding and non-responding students.
ii) Where the Danish data use birth dates, the American data rely on self-reported ages, which could be ticked in intervals, hence the difference in reporting.
iii) The US data have an overrepresentation of women in the sample as compared with the actual gender distribution of engineering students. In total, 19.5% of the US population of engineering students in this year's group is female [43].

Table 2. Mapping of core variables across survey instruments

Core variables	Survey Instruments	
	APPLES US 2008	Engineering Student Survey DK 2010
Importance of Skills in the Engineering Profession	Perceived Importance of Math and Science Skills (3 items) Perceived Importance of Professional and Interpersonal Skills (6 items)	
Confidence in Skills	Confidence in Math and Science Skills (3 items) Confidence in Professional and Interpersonal Skills (6 items)	
Motivation to Study Engineering	Financial Motivation (3 items) Family Influence (2 items) Social Good Motivation (3 items) Mentor Influence (4 items) Intrinsic Motivation (5 items)	
Demographics	Gender	

challenges.[1] Table 2 presents the core variables and items that the surveys have in common, which form the basis of the analyses in this paper.

The first core variable in Table 2 refers to the survey items that ask the students to report their perceived importance of a range of skills related to the engineering profession. The individual items on engineering skills are inspired by the requirements put forward by the ABET and the National Academy of Engineering and are aligned with literature on the desired engineering skills of the future as proposed by the Tuning Association [30] and in ongoing European discussions regarding two paradigms of engineering teaching—Conceive, Design, Implement, Operate (CDIO) [14] and problem-based learning (PBL) [48].

This paper focuses on the interplay between students' perceived importance of two types of skills, namely math and science skills and what is referred to as interpersonal and professional skills. The American and Danish respondents are placed in four different groups[2] according to their level of perceived importance of these two types of skills as compared with the other students in their country. Differences and similarities in confidence levels and motivation (the following core variables in Table 2) between the four groups within each country and across countries are investigated.

3.2 Weighting

All Danish analyses are based on weighted figures, due to the availability of precise knowledge about the representativeness of respondents to the population with respect to a range of background variables (type of program and institution, age, gender). The weighting gives more precise population level information and takes into consideration a skewed representation of the different Danish engineering education institutions by assigning the responses from students at underrepresented schools a larger weight. As for the US data, we do not have a similar

[1] For more information on the methods applied in the surveys, please refer to [43–45] respectively.

[2] The quadrant method for grouping students was inspired in part by Otto et al (2010) [49] and Brunhaver et al (2011) [50] who followed similar approaches but included confidence among their distinguishing parameters.

Table 3. Index construction and reliability test overview

Research Variable and *Survey Question*	Response categories[i]	Items	Constructed index	Reliability test: Cronbach's alpha US 2008	DK 2010
Importance of skills for becoming a successful engineer: *How important do you think each of the following skills and abilities is to becoming a successful engineer?*	Not important Somewhat important Very important Crucial I prefer not to answer/Do not know	Self confidence (social) Leadership ability Public speaking ability Communication skills Business ability Ability to perform in teams	**IPP Importance;** Perceived importance of interpersonal and professional skills	0.83 N=831	0.75 N=3305
		Math ability Science ability Ability to apply math and science principles in solving real world problems	**M/S Importance;** Perceived importance of math/science skills	0.80 N=831	0.75 N=3436

i) Due to differences in survey traditions and the fact that Danish students could just skip any question and move on to the next question if they preferred not to answer, the choice of "I prefer not to answer" in APPLES was replaced by a choice of "Do not know" in the Danish context. Responses in either of these categories are treated as missing values.

Table 4. Mean perceived importance of Math/Science skills and Interpersonal and Professional skills

Index means on a scale from 0 to 100 where the value 0 corresponds to "not important" answers to all items, and 100 indicates "crucial" answers to all items in the index.		US 2008	DK 2010
IPP Importance; Perceived Importance of Interpersonal and Professional Competencies (6 items)	Mean:	**68.4**	**60.0**
	St.deviation:	18.0	15.8
	S.E. of mean:	0.62	0.28
	N:	831	3305
M/S Importance; Perceived Math/Science Importance (3 items)	Mean:	**86.8**	**77.0**
	St.deviation:	16.1	17.6
	S.E. of mean:	0.56	0.30
	N:	831	3436

population level insight to inform the development of relevant weights, but we do know that there is an overrepresentation of women engineering students. As a result, these data are analyzed and presented separately, where appropriate.

3.3 Grouping of the students—the Quadrant Model

The grouping of the engineering students took place after a series of tests were run to ensure that the students replied to the items within each core variable in similar ways. These results indicated that the items comprising these variables were actually considered to be one coherent dimension in the eyes of the students.

In both surveys there were nine individual items that shed light on how students assessed these engineering skills. A factor analysis on the data collected showed that these nine distinct skills and abilities formed two dimensions consisting of the same three and six items, respectively. This is a good indicator that the items are construed as referring to two latent variables.[3] The two dimensions are referred to as *Perceived Importance of Math/Science (M/S) skills* and *Perceived Importance of Interpersonal and Professional (IPP) skills*. Question and response formulation and constituent items are found in Table 3, along with the results of the index reliability tests.

When comparing the actual levels of the engineering students' importance estimates of the two types of skills, the American engineering students ascribe higher importance than the Danes to both types of skills (Table 4). Danes appear to be more hesitant to give high importance estimates as compared with their American counterparts. This could be due to cross-cultural differences in response styles rather than to differences in actual levels of importance estimates. Culturally speaking, Danes are known to be somewhat reserved and not overly extreme in their communication styles [51, 52].

To avoid any over-interpretations of cross-national differences we will compare the groups of respondents that are above or below the median level of perceived importance of each of the two types of skills *within* each country. In other words, we compare the two groups of American freshmen who fall above or below the American student medians and, similarly, the two groups of newly enrolled Danish engineering students who fall above or below the Danish medians.

[3] The factor analysis was a PCA, principal component analysis, oblimin with Kaiser normalization, a standard non-orthogonal factor analysis type which gives precise, but correlated dimensions. The two dimensions explain 58% and 53% of the variance across the item responses in the US and the Danish data, respectively.

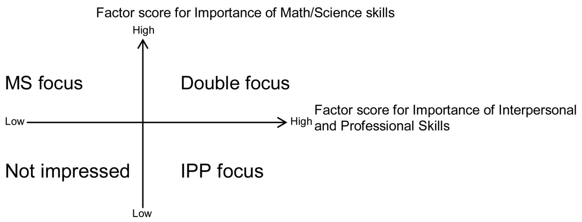

Fig. 1. The four groups according to perceived importance of Math/Science skills and Interpersonal and Professional skills.

The different items were not equally important on each of the dimensions, and in order to give the most accurate estimate of the latent variable behind the response behavior and to eliminate as much statistical noise as possible, factor scores for each of the two dimensions were calculated for each case or respondent. This results in a less intuitive estimate than index construction, but this is a more precise indicator of a coherent, underlying dimension as reflected by the actual response behavior of the engineering students.

Any hypothesis that a high estimate of the importance of one of the two skill types should correspond with a high importance estimate of the other can be rejected. There is no systematic relationship between the perceived importance of each of the two types of skills in engineering. This makes it possible to distinguish the four different and fairly large groups characterized by a combination of above or below median perceived importance level of each skill type.

Median instead of mean was chosen in order to secure approximate equal group sizes above and below this analytical distinction.

Students who report a combination of a level of perceived importance above the medians for both types of skills, we refer to as having a *double focus*, whereas a perceived level of importance below the median in either of the two skills in combination with an above median level of the other is referred to as having an *interpersonal and professional focus* or a *math/science focus*, respectively. Students who exhibit a combination of below median perceived levels of importance of both types of skills are referred to as *not impressed*. See Fig. 1. The naming of the latter group does not in any way indicate that the students in this group are considered less impressed by their education or any other matters. In this context, they do not recognize the two types of skills as highly important engineering skills, hence they are considered unimpressed with the importance of the skill types presented to them in the survey instruments.

3.4 Index construction

In order to investigate any differences in the average scores of the four groups in relation to confidence and motivation, indexes were constructed to provide valid and intuitive measures of the students' levels of confidence in M/S skills and IPP skills respectively and of different aspects of student motivation.

3.4.1 Confidence

The confidence of the engineering students was estimated by means of survey questions with Likert scale response options where they were asked to rate themselves compared with their classmates. The skills they were asked to assess were the same nine skills that were part of the importance assessment. (See Table 5 for exact questions, response categories and results of reliability testing.) The confidence rating came before the importance question out of consideration for the response sets and context effect [53 pp. 107, 66–68]. As with the importance question, factor analyses[4] showed that the items formed one dimension, reflecting confidence in interpersonal and professional skills (consisting of six items) and another dimension reflecting math/science skills (three items). Two indexes were constructed to assess students' confidence in each of those two overall types of skills. Indexes were constructed after reliability testing.

3.4.2 Motivation

Both APPLES and the Danish survey included a subset of questions on student motivation. (See the questions, response categories, and reliability test results in Table 6.) The 16 shared items on motivation in both surveys were for the most part intended to estimate different aspects of motivation known from previous education research and the thereby derived insights into the cognitive and psychological aspects of motivation [43, 44]. It is important to note that level of motivation is not an indicator of how motivated the student is; it is an indicator of how important the particular motive has been for the student's choice of education. When exploring the data inductively, students seem to respond to the latent variables similarly to the expected ones. The factor analyses resulted in five dimensions in both

[4] Factor analysis was performed to identify latent dimensions in the respondents' understanding and responding to the survey questions on confidence and motivation. Each latent dimension was validated by means of criteria validity testing of the included items and cross-checking of their uni-dimensionality. The method used for the factor analysis was a PCA, principal component analysis, oblimin with Kaiser normalization, a non-orthogonal rotated factor analysis type. This allowed us to determine precise but correlated dimensions in the survey. As for the confidence items, 62% of the variance on the nine items was explained by the two dimensions among the American freshmen engineering students. Among the Danish engineering students in their first month of studies, 55% of the variance in the items was explained by the dimensions consisting of the same three and six items. For more methodical details cf. [43 and 45].

Table 5. Confidence index construction and reliability test overview

<table>
<tr><th rowspan="2">Research Variable and Survey Question</th><th rowspan="2">Response categories[i]</th><th rowspan="2">Items</th><th rowspan="2">Constructed index</th><th colspan="2">Reliability test: Cronbach's alpha</th></tr>
<tr><th>US 2008</th><th>DK 2010</th></tr>
<tr><td rowspan="9">Confidence in skills:

Rate yourself on each of the following skills as compared to your classmates. We want the most accurate estimate of how you see yourself.</td><td rowspan="9">Lowest 10%

Below average

Average

Above average

Highest 10%

I prefer not to answer/Do not know</td><td>Self confidence (social)</td><td rowspan="6">Confidence in interpersonal and professional skills</td><td rowspan="6">0.83
N=827</td><td rowspan="6">0.77
N=3265</td></tr>
<tr><td>Leadership ability</td></tr>
<tr><td>Public speaking ability</td></tr>
<tr><td>Communication skills</td></tr>
<tr><td>Business ability</td></tr>
<tr><td>Ability to perform in teams</td></tr>
<tr><td>Math ability</td><td rowspan="3">Confidence in math/science skills</td><td rowspan="3">0.82
N=829</td><td rowspan="3">0.77
N=3320</td></tr>
<tr><td>Science ability</td></tr>
<tr><td>Ability to apply math and science principles in solving real world problems</td></tr>
</table>

i) Due to differences in survey traditions and the fact that Danish students could just skip any question and move on to the next question if they preferred not to answer, the choice of "I prefer not to answer" in APPLES was replaced by a choice of "Do not know" in the Danish context. Responses in either of these categories are treated as missing values.

the Danish and the American data that corresponded to the following latent variables that were constructed as indexes[5] (see Table 6 for constituent items and reliability test results and Sheppard et al. [43] for more background on the theoretical aspects of engineering student motivation):

- *Intrinsic motivation* is construed as motivation stemming from personal experiences and feelings in connection to engineering-related activities. It was expected that we would find two distinct latent variables reflecting intrinsic psychological and intrinsic behavioral motivation respectively, but the students' responses to all five items were represented as one coherent dimension which, for the purpose of this paper, we refer to as intrinsic motivation.
- *Social good motivation* has to do with reasons for becoming an engineer that are rooted in the expectation that, as an engineer, one will be able to contribute to society.
- *Financial motivation* is the umbrella term for reasons for pursuing engineering in order to achieve a financially awarding career.
- *Parental motivation* is used to describe students' conceptions of their parents' influence on their decision to choose an engineering career. It is important to bear in mind that these estimations—as with the others—are self-reported, which means that this is not a measure of social inheritance in terms of parental background, values, etc. that may unconsciously influence the educational strategies of young people. This index refers to how parents' wishes or expectations reportedly affect students' reasons for pursuing an engineering degree.
- *Mentor motivation* consists of four items and covers the extent to which the decision to study engineering was due to the influence of mentor(s).

3.5 *Statistical testing*

To characterize the groups defined by this quadrant model and investigate if they were actually unique and independent of each other, gender distribution, group confidence, and motivation levels were compared. Analyses of the four groups of above or below median levels of perceived importance of math/science skills and professional and interpersonal skills were performed using one-way analysis of variance (ANOVA and Kruskall–Wallis H test) to identify whether statistically significant differences of the four different groups in relation to the analyzed variables existed. In cases where the tested variables were normally distributed for all four groups and homogeneity of variance assumptions were met, the ANOVA test was used. In cases where the assumption of homogeneity of variance was breached, the Welch Robust Test of Equality of means was used. The ANOVA test is considered rather robust to breaches of the assumption of normal distribution. In any case, the Kruskal–Wallis H test, which is the non-parametric equivalent to an ANOVA test, better suited to non-normally distributed variables, was used as a more conservative analysis approach in cases where a normal distribution was violated. The Kruskal–Wallis test does not compare group means, but gives statistically significant evidence of group differences due to test scores based on rankings and group medians. For post hoc tests, Tukey was used

[5] One item ("A faculty member, academic advisor, teaching assistant or other university affiliated person has encouraged and/or inspired me to study engineering") loaded on two dimensions in the Danish data, namely mentor influence and parental influence. We decided to include this item in the mentor dimension in order to align with previously validated findings in the US context [43, 44].

Table 6. Motivation index construction and reliability test overview

Research Variable and *Survey Question*	**Response categories**[i]	**Items**	**Constructed index**	**Reliability test: Cronbach's alpha**	
				US 2008	DK 2010
Motivation: *We are interested in knowing why you are studying engineering. Please indicate below the extent to which the following reasons apply to you:*	Not a reason for my choice of education[ii] Minimal reason for my choice of education Moderate reason for my choice of education Major reason for my choice of education I prefer not to answer/Do not know	I feel good when I am doing engineering I like to build stuff I think engineering is fun I think engineering is interesting I like to figure out how things work	**Intrinsic motivation**	0.85 N=807	0.81 N=3332
		Technology plays an important role in solving society's problems Engineers have contributed greatly to solving problems in the world Engineering skills can be used for the good of society	**Social good motivation**	0.75 N=825	0.75 N=3484
		Engineers make more money than most other professionals Engineers are well paid An engineering degree will guarantee me a job when I graduate	**Financial motivation**	0.80 N=826	0.75 N=3451
		My parent(s) would disapprove if I chose a major other than engineering My parent(s) want me to be an engineer	**Parental influence**	0.78 N=831	0.72 N=3482
------------------ *Please indicate how strongly you disagree or agree with each of the statements:*	------------------ Disagree strongly Disagree Agree Agree strongly I prefer not to answer/Do not know	A faculty member, academic advisor, teaching assistant or other university affiliated person has encouraged and/or inspired me to study engineering A non-university affiliated mentor has encouraged and/or inspired me to study engineering A mentor has introduced me to people and opportunities in engineering ------------------ A mentor has supported my decision to study engineering	**Mentor motivation**	0.75 N=792	0.59 N=3216

i) Due to differences in survey traditions and the fact that Danish students could just skip any question and move on to the next question if they preferred not to answer, the choice of "I prefer not to answer" in APPLES was replaced by a choice of "Do not know" in the Danish context. Responses in either of these categories are treated as missing values.
ii) The US response categories did not contain "...for my choice of education". In the Danish pre-survey testing misunderstandings of the question were uncovered that were sought avoided with this addition.

when breaches of homogeneity of variance did not take place and when group sizes were approximately the same; otherwise the Games–Howell post hoc test was used to assess where statistically significant differences occurred between groups.

4. Presentation

This section provides more knowledge of the students who perceive M/S skills and IPP skills in these four different ways in order to qualify efforts to push engineering students towards acknowledging the value of both kinds of skills as important engineering skills. First, the four groups are described in terms of their relative group sizes and the gender distribution. Next, the extent to which the double focused, the math/science focused, the IPP focused, and the unimpressed differ from each other in terms of general confidence levels and motivation is examined. Figure 2 presents an overview of the overall findings.

4.1 Gender composition and group sizes

The double focused, the M/S focused, the IPP focused, and the unimpressed engineering students in the US and in Denmark are described in terms of gender representation and dispersion of the population in the four groups.

As shown in Table 7, there is a larger share of female than male engineering students in the group that focuses on IPP skills; this is also reflected in the double focused group. This suggests that women engineering students, to a larger extent than their male counterparts, acknowledge the importance of

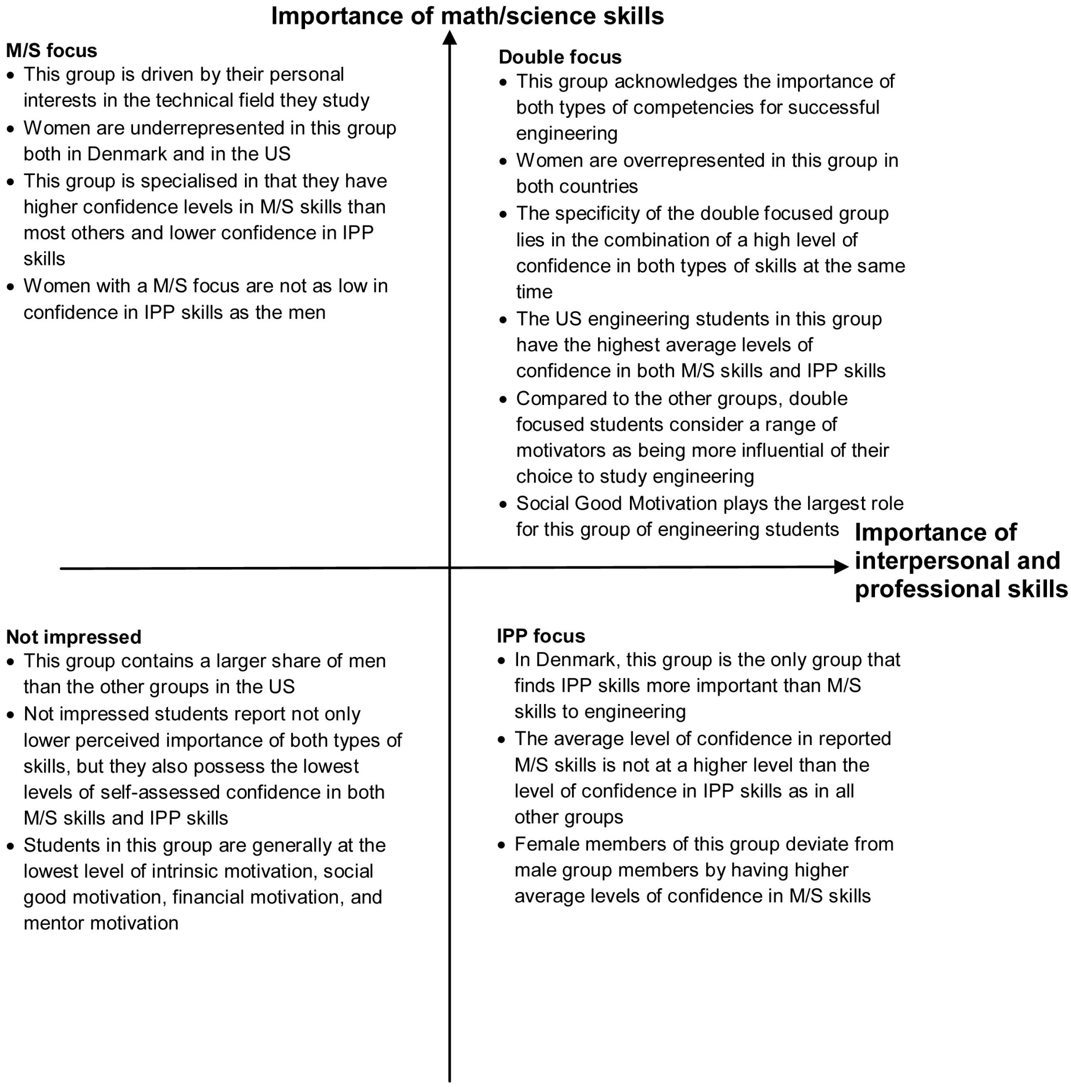

Fig. 2. Overview of the four group profiles.

both M/S skills and IPP skills to engineering. The group of not impressed engineering students who have a lower (below median) perception of the importance of both types of skills has an over-representation of men as compared with women in the US, but this is not the case in Denmark. In both countries, women are underrepresented in the group of students that is focused primarily on math/ science skills. In Denmark, 76% of the entire year group is male but in the M/S focused group, as many as 84% are men.

Table 7. Gendered representation of the four groups in each country.

	APPLES Freshmen			DK10		
	F	M	Total	F[i)]	M	Total
Double focused	34	30	31	33	25	27
IPP focus	21	18	19	25	22	23
MS focus	16	21	19	16	25	23
Not impressed	29	32	31	27	27	27
Total	100	100	100	100	100	100
N	300	529	829	753	2505	3258

Percentages.
i) Statistically significant deviation from total distribution according to the chi square goodness of fit test ($p < 0.001$).

First year engineering students in the US tend to be somewhat more polarized than the Danish in their importance groupings. Whereas Danish engineering students are almost evenly distributed in each group, the Americans tend to huddle together in the extremes—in the double focused and the not impressed groups.

4.2 *Confidence*

This section describes the four groups of the quadrant model and examines whether these groups are statistically significantly different from each other in their levels of confidence in their own math/science skills and interpersonal and professional skills. See Table 8.

When looking at engineering students' confidence in the two types of skills, we see that three of the four groups of first year engineering students in both countries have higher average levels of confidence in math/science skills than in interpersonal and professional skills. The only exception is the IPP focused group. Among the American freshmen engineering students, this group has the same average level of confidence in both types of skills. In Denmark, the IPP focused group has statistically significantly higher confidence in interpersonal and professional skills than in math/science skills. In this way, the Danish IPP group is the only group with higher average level of confidence in IPP skills than in M/S skills. The other Danes do not deviate from the American students in the corresponding profiles when it comes to the relative levels of confidence in the two types of skills.

As when analyzing perceived importance, the Danes tend to state somewhat lower levels of confidence than Americans but their answers are only slightly less dispersed along the scale than those of the American respondents, which suggests almost the same degree of deviation from the average answers in both national contexts.

In both countries, the highest statistically significant average of math/science confidence levels are seen in the math/science focused groups and in the double focused groups, and the highest statistically significant average levels of confidence in IPP skills are found in the IPP focused groups and the double focused groups. This means that the groups who are focused on only one type of skill area are not very confident in the other type. This suggests that these groups are more specialized in their competence profiles than the others, assuming that self-assessed confidence levels reflect actual competencies.

In Denmark, the double focused group ranks second in average confidence in both types of skills, which suggests that the combination of high levels of both skill types takes place at the expense of top rankings in confidence levels. The top mean levels of confidence in each skill type are found in the group that focuses on the importance of each of these types of skills. This is not the case among the American freshmen, where the double focused group has the highest levels of confidence in both types of skills, although the difference in mean levels of IPP confidence between the double focused group and the IPP focused group is too small to be statistically significant. It holds for both countries that the not impressed group, consisting of those with the lowest levels of perceived importance of both types of skills, is also the group with the lowest average levels of confidence in both types of skills. Among the US engineering freshmen, though, the mean level of IPP confidence of the not impressed group is 62 on a scale of 0–100. This appears to be slightly higher than the average level for the M/S focused group (mean = 61), but the size of this difference is too small to be statistically significant. In Denmark, there is also no statistically significant difference in the mean IPP confidence levels of the not impressed group and the M/S focused group.

Table 8. Confidence of the four groups.

	IPP confidence		M/S confidence	
	US 2008	**DK 2010**	**US 2008**	**DK 2010**
Double	M: 71 SEM: 1.0 SD: 16 N: 258	M: 63 SEM: 0.5 SD: 15 N: 833	M: 76 SEM: 1.1 SD: 17 N: 258	M: 65 SEM: 0.6 SD: 17 N: 866
IPP	M: 70 SEM: 1.3 SD: 16 N: 156	M: 67 SEM: 0.5 SD: 14 N: 713	M: 70 SEM: 1.3 SD: 16 N: 157	M: 59 SEM: 0.6 SD: 15 N: 720
M/S	M: 61 SEM: 1.3 SD: 16 N: 154	M: 57 SEM: 0.6 SD: 16 N: 687	M: 73 SEM: 1.5 SD: 18 N: 155	M: 68 SEM: 0.6 SD: 17 N: 715
Not impressed	M: 62 SEM: 0.9 SD: 15 N: 258	M: 56 SEM: 0.5 SD: 15 N: 822	M: 68 SEM: 1.1 SD: 18 N: 256	M: 58 SEM: 0.5 SD: 16 N: 861
Total	M: 66 SEM: 0.6 SD: 16 N: 826	M: 61 SEM: 0.3 SD: 16 N: 3054	M: 72 SEM: 0.6 SD: 18 N: 826	M: 62 SEM: 0.3 SD: 17 N: 3163

Index means on a scale of 0–100, where the value 0 corresponds to "Lowest 10%" answers to all items, and 100 indicates "Highest 10%" answers to all items in the index. Standard error of mean (SEM), standard deviation (SD), and population (N) of each group are also reported. The braces indicate statistically significant differences between groups ($p < 0.001$).

Furthermore, there is no statistically significant difference in the M/S confidence levels of the not impressed group and the IPP focused group.

The four group profiles are very similar across the two nations. Each of the four types of profiles seems to respond in comparable ways across the two countries to confidence questions, which indicates that the model is a fairly good indicator of the overall differences found in confidence levels.

4.3 Motivation to study engineering

Engineering students in the four different groups also appear to have different profiles when it comes to their motivation to study engineering. Contrary to what we find elsewhere, there is no large difference between American and Danish respondents in the range of their answers to the motivation questions. On a 0–100 point scale the average level of intrinsic motivation is the same for the total of American freshmen as for the total of newly enrolled Danish engineering students, namely 79 (standard deviations are 21 and 19, respectively, which does indicate, though, that the US engineering students vary slightly more in their responses than the Danes) (See Tables 9 and 10).

4.3.1 Intrinsic motivation

Intrinsic motivation is the main reason for most engineering students in both countries to have chosen their field of education. Regardless of external influences, these students are mainly affected by internal motives.

The profile of the four groups is similar across the two countries in regards to the tendency of the double focused group to be more intrinsically motivated than the not impressed group, in particular.

There is a slightly larger dispersion of the average level of intrinsic motivation of the four groups in Denmark than in the US, but the most remarkable difference between the two countries is perhaps the different tendencies of the M/S focused groups in the two countries. In Denmark this group has the highest mean level of intrinsic motivation compared with the other groups, whereas in the US, M/S focused students are at an average level.

4.3.2 Social good motivation

With respect to social good motivation, a similar pattern can be found across the four groups in Denmark and in the US. In both countries, the double focused group is on average the most motivated to study engineering in order to contribute to society, followed by the IPP focused group and the M/S focused group. Finally, the not impressed group is in both countries the group to whom this motive plays the smallest role in their choice of education. There may be a general cultural difference in the strength of this motive that manifests itself in higher levels of social good motivation among all American engineering students compared with the four Danish groups. However, this tendency affects all four groups in the same way, which suggests that the four profiles still differ from each other in similar ways across the two nations.

4.3.3 Financial motivation

The impact of the financial crisis over the last few years did not cause Danish engineering students to express the same level of financial motivation as the American students reported two years earlier. Financial motivation appears to be more important in the American context than in Denmark as explained by profound differences in societal structures and cultural values. The main tendency of the four profiles across countries in relation to financial motivation is that of the double focused group reporting a higher mean level than the not impressed group in particular. The main differences across the two countries are seen in the IPP focused group in Denmark being on a par with the double focused group in their mean level of financial motivation, which is not the case in the US; apparently, financial motivation is a less divisive issue in Denmark than in the US.

4.3.4 Mentor motivation

A surprisingly similar pattern in group profiles across the countries as well as in the actual levels of mentor motivation for the four groups is shown. The double focused and the IPP focused groups are at the highest average levels of mentor motivation in both countries followed by the M/S focused and the not impressed group. The fact that Danes seem to feel motivated by people in what they construe as a mentoring role in spite of the absence of an institutionalized mentor system sheds light on the influential role of personal relations or role models who can inspire young people and support their decisions to opt for an engineering education. In Denmark, where women tend to give systematically "lower" responses than men, mentor motivation gives a different picture (as shown in Table 11). Mentoring seems to play a slightly more important role to newly enrolled female engineering students in Denmark than to their male counterparts.

This finding indicates that there may be a potential opportunity to inspire more Danes—particularly women—to study engineering through more systematic and strategic encouragement of mentoring activities.

4.3.5 Parental motivation

The influence of parents in the choice of an engineering education appears to be a more limited

Table 9. Motivation of the four groups (intrinsic, social good, financial)

	Intrinsic motivation		Social good motivation		Financial motivation	
	US 2008 *	DK 2010 ***	US 2008 ***	DK 2010 ***	US 2008 ***	DK 2010 **
Double	M: 81 SEM: 1.2 SD: 19 N: 250	M: 82 SEM: 0.6 SD: 18 N: 813	M: 82 SEM: 1.3 SD: 20 N: 255	M: 75 SEM: 0.7 SD: 21 N: 851	M: 73 SEM: 1.3 SD: 21 N: 256	M: 58 SEM: 0.8 SD: 24 N: 829
IPP	M: 80 SEM: 1.7 SD: 21 N: 150	M: 78 SEM: 0.7 SD: 19 N: 693	M: 80 SEM: 1.5 SD: 19 N: 154	M: 71 SEM: 0.8 SD: 22 N: 716	M: 67 SEM: 2.1 SD: 27 N: 156	M: 58 SEM: 0.9 SD: 23 N: 708
M/S	M: 79 SEM: 1.6 SD: 20 N: 154	M: 83 SEM: 0.6 SD: 17 N: 693	M: 75 SEM: 1.7 SD: 21 N: 156	M: 68 SEM: 0.9 SD: 25 N: 726	M: 69 SEM: 2.0 SD: 25 N: 154	M: 55 SEM: 0.9 SD: 25 N: 716
Not impressed	M: 76 SEM: 1.4 SD: 22 N: 251	M: 74 SEM: 0.7 SD: 20 N: 833	M: 72 SEM: 1.5 SD: 25 N: 258	M: 64 SEM: 0.8 SD: 24 N: 852	M: 64 SEM: 1.6 SD: 25 N: 258	M: 55 SEM: 0.8 SD: 23 N: 867
Total	M: 79 SEM: 0.7 SD: 21 N: 805	M: 79 SEM: 0.3 SD: 19 N: 3032	M: 77 SEM: 0.8 SD: 22 N: 823	M: 69 SEM: 0.4 SD: 24 N: 3145	M: 68 SEM: 0.9 SD: 24 N: 824	M: 57 SEM: 0.4 SD: 24 N: 3120

Index means on a scale of 0–100, where the value 0 corresponds to ''Not a reason for my choice of education'' answers to all of the items, and 100 represents ''Major reason'' answers to all of the items in the index. Standard error of mean (SEM), standard deviation (SD), and population (*N*) of each group are also reported. The braces indicate statistically significant differences between groups.
Significance levels: * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

Table 10. Motivation of the four groups (mentor, parental)

	Mentor motivation		Parental motivation	
	US 2008 **	DK 2010 ***	US 2008 ns	DK 2010 ***
Double	M: 40 SEM: 1.6 SD: 25 N: 249	M: 40 SEM: 0.8 SD: 22 N: 785	M: 16 SEM: 1.5 SD: 25 N: 258	M: 7 SEM: 0.5 SD: 16 N: 865
IPP	M: 41 SEM: 2.0 SD: 25 N: 151	M: 38 SEM: 0.8 SD: 21 N: 682	M: 18 SEM: 2.2 SD: 27 N: 157	M: 10 SEM: 0.7 SD: 19 N: 707
M/S	M: 35 SEM: 1.9 SD: 23 N: 146	M: 35 SEM: 0.8 SD: 21 N: 667	M: 10 SEM: 1.4 SD: 17 N: 156	M: 7 SEM: 0.6 SD: 15 N: 722
Not impressed	M: 34 SEM: 1.6 SD: 25 N: 245	M: 32 SEM: 0.7 SD: 19 N: 791	M: 17 SEM: 1.5 SD: 25 N: 258	M: 6 SEM: 0.5 SD: 14 N: 863
Total	M: 38 SEM: 0.9 SD: 25 N: 791	M: 36 SEM: 0.4 SD: 21 N: 2926	M: 16 SEM: 0.8 SD: 24 N: 829	M: 7 SEM: 0.3 SD: 16 N: 3157

Index means on a scale of 0–100, where the value 0 corresponds to ''Not a reason for my choice of education'' answers to all items, and 100 indicate ''Major reason'' answers to all items in the index. Standard error of mean (SEM), standard deviation (SD), and population (*N*) of each group are also reported. The braces indicate statistically significant differences between groups.
Significance levels: ns = not significant, * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$

Table 11. Gender difference in mentor motivation in Denmark

	DK 2010 Females	DK 2010 Males	Significance level of gender difference
Mentor motivation	M: 40 SD: 20 SEM: 0.7 N: 779	M: 35 SD: 21 SEM: 0.4 N: 2436	p< 0.001

Index means on a scale of 0–100, where the value 0 corresponds to ''Not a reason for my choice of education'' answers to all items, and 100 indicates ''Major reason'' answers to all items in the index. Mean (M), standard deviation (SD), standard error of mean (SEM), and population (*N*).

contributor to motivation for Danish students than for the US students. The IPP focused groups report higher levels of parental motivation than the other groups, but the difference between top and bottom levels is so small in Denmark that the issue simply does not contribute much to the descriptive differences among the four profiles. In the US, the differences—although larger—are not statistically significant.

5. Discussion

The members of the *not impressed* group do not consider any of the skills as very important to engineering, nor do they express much confidence in them. At the same time, they report the lowest scores on intrinsic motivation, social good motivation, financial motivation, and mentor motivation. This does not necessarily mean that they are not as motivated as the other groups, their motivation could be due to entirely different factors that were not captured by the survey instruments, or their motives to study engineering could be somewhat unclear to the students themselves and therefore were not reported. The characteristics of this group call for special attention by engineering education professionals. Confidence and motivation are crucial for engineering student success and retention, and this group may need specific support to build their confidence, settle into the new educational environment, and become more self-aware about their motives to study engineering.

A remarkable difference in motivation to study engineering was found between the not impressed group and the remaining engineering students. The actual mean motivation scores was below that of all the other groups in relation to intrinsic motivation, social good motivation, financial motivation, and mentor motivation (the groups' means were statistically significantly lower than those of all the other three groups in the Danish dataset and either at the same level as or statistically significantly lower than that of the other groups of American freshmen engineering students). These findings highlight the possible need for more valid or detailed measures of capturing students' particular reasons for attending an engineering degree program or that the students are not very clear themselves about their reasons for making this choice.

In contrast, the double focused students tended to report the highest average group means for all motivation type except for parental motivation.

While the American IPP focused and double focused groups had the same levels of intrinsic and social good motivation, all four groups had the same rankings of the motivation types with intrinsic motivation having the highest average score, followed by social good motivation, financial motivation, mentor influence, and finally parental influence as the least influential in students' decisions to pursue engineering education. Clearly, motivation is not equally distributed across different types of motivation. These motivation types do not replace each other, and there is no indication that one type of motivation is the main motivator for one group of students as opposed to the others. Membership in one of the four groups does not correlate with differences in motivations to study engineering—only with the strength or degree of these motivations. Apparently, the students study engineering for a multitude of reasons. However, students who are above the median level in their estimate of the importance of either math/science skills, interpersonal and professional skills, or both, tend to have stronger feelings that all of these factors—except for parental influence—have contributed to their decision to pursue engineering as compared with those in the not impressed group.

The *math/science focused* group and the group with an *interpersonal and professional focus* are both specialized in that they combine high levels of perceived importance of one skill type with a low importance estimate of the other. When it comes to estimating one's own levels of confidence, the specialization of the two groups is also marked. The M/S focused group has high levels of M/S confidence and low levels of IPP confidence. In general, the students' level of M/S confidence is above that of their reported IPP confidence, but this is not the case among IPP focused engineering students. IPP focused engineering students are somewhat more motivated by desires to do societal good, by mentor influence, and by parental influence as compared with the M/S focused students. Women are also slightly overrepresented in the IPP group and underrepresented in the M/S focused group.

The specific needs of these two specialized groups could include the overturning of some prejudices and stereotypes. For example, the M/S focused men might view interpersonal and professional skills as being "soft" and not as critical as technical knowledge and expertise. In addition, IPP focused students may view students in the M/S group as "geeky" and socially inept. When teaching these two groups, the first challenge lies in opening their eyes to the importance of the skill type they do not initially consider important to engineering. Then educating and fostering the development of these skills can take place, which may result in greater confidence and understanding as well as better potential for broad thinking.

The *double focused* students enter the engineering education system already very knowledgeable of the importance of both types of skills. They have high levels of both M/S and IPP confidence and are at the top levels of social good motivation, intrinsic, mentor, and financial motivation. There is a higher than average likelihood that the double focused engineering student is a woman. This group could be at the greatest risk for disappointment once they become more familiar with engineering because their expectations seem to be more advanced and mature than those of the other groups. These students could be a valuable resource in the classroom and in extra-curricular activities where their motivation and confidence could be assets for both the instructors as well as their fellow classmates.

The role of mentoring among Danish students—especially women—gives rise to considerations of potential gains from introducing more institutionalized mentoring systems earlier in the educational system in order to recruit young Danes to the field of engineering. The mere fact that women are more likely to be double focused than men suggests that the study environment could be enhanced and expanded by attracting more women to engineering.

6. Conclusion

Based on self-assessments by engineering students of what it takes to become a successful engineer, four profiles were identified and compared across two different nations. These engineering student profiles were distinguished by means of their perceived importance of math/science skills and interpersonal and professional skills. This led to the development of a quadrant model that has uniquely demonstrated a range of differences in various parameters in the US and in Denmark. These four groups have very similar profiles across the two countries.

The cross-country differences found in the group profiles showed a small overrepresentation of men in the not impressed group in the US, which was not seen in the Danish sample. In Denmark, the importance of mentoring is higher among women than men. In addition, the Danish double focused group did not have the highest rankings in confidence scores as was seen in the US. In Denmark, the double focus appeared to detract from students' confidence levels in both types of skills, whereas the M/S and IPP specialized groups reported the highest levels of confidence with the double focused students falling just behind them.

These four different profiles seem to have unique views of what it takes to become a good engineer, as well as different characteristics in terms of gender, motivation, and confidence levels. It seems, the not impressed group consisting of the students who are the most in disagreement with engineering education theorists on what skills it takes to become a successful engineer diverge somewhat from the other three groups of students.

The identification of these four groups qualifies efforts by engineering education systems to support the developmental pathways of first year engineering students into full-fledged engineers who are capable of thinking broadly in their problem solving approaches to today's global challenges. By emphasizing the different characteristics that each of these groups possess when they enter engineering programs and institutions, faculty, researchers, and staff can focus on designing more effective and impactful educational strategies that address the specific needs of these students

Acknowledgements—The financial support for the Danish research from The Danish Strategic Research Council through the Program of Research on Opportunities and Challenges in Engineering Education in Denmark (PROCEED) is gratefully acknowledged, as is the collaboration with Jette Egelund Holgaard, Aalborg University. Additionally, the final support by the National Science Foundation under Grant No. ESI-0227558 is acknowledged, as well as all of the collaborating partners and schools in the Center for the Advancement of Engineering Education (CAEE), in particular, Ken Yasuhara, Micah Lande, and Ryan Campbell. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NSF.

References

1. S. H. Christensen, B. Delahousse and M. Meganck, *Engineering in Context*, Academica, Aarhus, 2009.
2. ABET, *Sustaining the Change*, http://www.abet.org/sustaining-change, 2004. Accessed 6 September 2012.
3. ABET, *Engineering Change*, executive summary, http://www.abet.org/engineering-change, 2006. Accessed 6 September 2012.
4. P. J. Armstrong, E. Crawley, J. Malmqvist, S. Östlund and D. Brodeur, The CDIO syllabus: Learning outcomes for engineering education, in E. Crawley, F. Malmqvist, S. Östlund and D. Brodeur (Eds.), *Rethinking Engineering Education*, Springer, USA, Ch. 3, pp. 43–76.
5. C. J. Atman and I. Nair, Engineering in context: an empirical study of freshmen students' conceptual frameworks, *Journal of Engineering Education,* 1996, pp. 317–326.
6. D. Bourg, Le développement durable ou peut-on enseigner ce qu'on ne connaît pas?, *Economie et humanisme*, **365**, 2003, p. 73ff.
7. D. Grasso, Engineering a liberal education, *Prism*, American Society of Engineering Education, **12**(2), 2002.
8. A. Jamison and N. Mejlgaard, Contextualising nanotechnology education—fostering a hybrid imagination in Aalborg, Denmark, *Science as Culture*, **19**(3), 2010, pp. 351–368.
9. National Academy of Engineering, Grand Challenges for Engineering, http://www.engineeringchallenges.org/cms/8996/9221.aspx, 2008. Accessed 6 September 2012.
10. NSF, National Science Foundation, SEES Portfolio, February, http://www.nsf.gov/geo/sees/sees_portfolio.jsp, 2011. Accessed 6 September 2012.
11. S. D. Sheppard, K. Macatanga, A. Colby and W. M. Sullivan, *Educating Engineers—Designing for the Future of the Field*, Jossey-Bass,The Carnegie Foundation for the Advancement of Teaching, 2009.
12. M. A. Abraham, Principles of sustainable engineering, in M. A. Abraham (ed.), *Sustainability Science and Engineering*, Elsevier, 2006, pp. 3–10.

13. J. A. Bowden, Capabilities-driven curriculum design, in C. Baillie and I. Moore (Eds.), *Effective Learning and Teaching in Engineering*, Routledge, 2004, pp. 36– 47.
14. E. Crawley, F. Malmqvist, S. Östlund and D. Brodeur, *Rethinking Engineering Education*, Springer, USA, 2007.
15. U. M. Emilsson and B. Lilje, Training social competence in engineering education: necessary, possible or not even desirable? An explorative study from a surveying education programme, *European Journal of Engineering Education*, **3**(33), 2008, pp. 259–269.
16. RAE,The Royal Academy of Engineering, in R. Dodds and R. Venables (Eds.), *Engineering for Sustainable Development: Guiding Principles*, London, http://www.raeng.org.uk/events/pdf/Engineering_for_Sustainable_Development.pdf, 2005. Accessed 6 September 2012.
17. EUR-ACE, *Framework Standards for the Accreditation of Engineering Programmes*, Accreditation of European Engineering Programmes and Graduates, http://www.jointquality.nl/content/descriptors/A1_EUR-ACE_Frwrk_Stds_Final_05_11_17.pdf, 2005. Accessed 6 September 2012.
18. T. B. Hansen, Scientific bildung for the post-normal epoch, in J. Christensen, L. B. Henriksen and A. Kolmos (Eds.), *Engineering Science, Skills, and Bildung*, Aalborg University Press, 2006, pp. 131–145.
19. L. B. Henriksen, Engineers and bildung, in J. Christensen, L. B. Henriksen and A. Kolmos (Eds.), *Engineering Science, Skills, and Bildung*, Aalborg University Press, 2006, pp. 43–60.
20. M. Heymann, Section introduction and Chapter 11. "Art" or science? Competing claims in the history of engineering design, in S. H. Christensen, B. Delahousse and M. Meganck (Eds.), *Engineering in Context*, Academica, Aarhus, 2009, pp. 223–244.
21. J. E. Holgaard, P. Bøgelund, A. Kolmos and M. Dahms, Master of Science as Change Masters, in J. Christensen, L. B. Henriksen and A. Kolmos (Eds.), *Engineering Science, Skills, and Bildung*, Aalborg University Press, 2006, pp. 187–208.
22. A. Jamison, The historiography of engineering contexts, in S. H. Christensen, B. Delahousse and M. Meganck (Eds.), *Engineering in Context*, Academica, Aarhus, 2009, pp. 49–60.
23. A. Jamison and J. E. Holgaard, The cultural appropriation of contextual knowledge, *Engineering Education in Sustainable Development 2008. Bridging the Gap*, Graz, Austria, 22–24 September 2008, pp. 270–277.
24. A. Jamison and N. Mejlgaard, The shadow of commerce, *PRISM,* American Society for Engineering Education, **19**(3), November 2009, p. 84.
25. U. Jørgensen, Historical accounts of engineering education, in E. Crawley, F. Malmqvist, S. Östlund and D. Brodeur (Eds.), *Rethinking Engineering Education*, Springer, USA, 2007, pp. 216–240.
26. D. Kilgore, C. J. Atman, K. Yasuhara, T. Barker and A. Morozov, Considering context: a study of first-year engineering students, *Journal of Engineering Education,* 2007 pp. 321– 334.
27. A. Kolmos, Future engineering skills, knowledge and identity, in J. Christensen, L. B. Henriksen and A. Kolmos (Eds.), *Engineering Science, Skills, and Bildung*, Aalborg University Press, 2006, pp. 165–185.
28. P. Kroes and I. Poel, Problematizing the notion of social context of technology, in S. H. Christensen, B. Delahousse and M. Meganck (Eds.), Academica, *Engineering in Context*, Aarhus, 2009, pp. 61–74.
29. B. Newberry, The dialectics of engineering, in S. H. Christensen, B. Delahousse and M. Meganck (Eds.), *Engineering in Context*, Academica, Aarhus, 2009, pp. 33–48.
30. TA, Tuning Association, *A Tuning-AHELO Conceptual Framework of expected/desired learning Outcomes in Engineering*, Tuning Association on behalf of a group of experts, OECD, 2009.
31. R. Williams, Education for the profession formerly known as engineering, *Chronicle of Higher Education,* 49(20), B12, 24 January 2003.
32. E. K. Graversen, Beregninger på værditilvæksteffekten af ændringer i FoU-kapital, andel FoU-personel eller andel forskeruddannede ansatte, working paper, The Danish Centre for Studies in Research and Research Policy, 2005.
33. S. Haase and E. K. Graversen, Innovation policy and societal challenges. European Trend Chart on Innovation, European Commission, DG Enterprise and Industry, 2009.
34. E. K. Graversen and S. Haase, INNO-Policy Trend Chart—Innovation Policy Progress Report DENMARK 2009, European Commission, DG Enterprise and Industry, 2009, http://www.proinno-europe.eu/www.proinno-europe.eu/extranet/upload/countryreports/Country. Accessed 6 September 2012.
35. A. Andersen, I. Fallentin, C. F. Frederiksen, M. S. Lysgaard and M. M. Nielsen, PISA—En skæv evaluering, thesis, Roskilde University, 2005.
36. Retsinformation, Declaration on the Public School, in Danish: *Folkeskoleloven*, 2010, https://www.retsinformation.dk/forms/r0710.aspx?id=133039. Accessed 6 September 2012.
37. The Danish Government, *Faglighed og Frihed*, December, 2010, http://www.uvm.dk/Service/~/media/UVM/Filer/Udd/Folke/PDF10/101208_Folkeskolereform_web.ashx
38. National Academy of Engineering, *Educating the Engineer of 2020. Adapting Engineering Education for the New Century,* National Academies Press, Washington DC, 2005. http://www.nap.edu/catalog/11338.html. Accessed 6 September 2012.
39. ABET, Criteria for Accrediting Engineering Programs, 2011–2012: General Criteria 3—Student Outcomes, 2012, http://www.abet.org/eac-current-criteria. Accessed 6 September 2012.
40. Pennsylvania State University, Center for the Study of Higher Education, *Engineer of 2020 Studies*, 2012, http://www.ed.psu.edu/educ/cshe/research/prototype-to-production-conditions-and-processes-for-educating-the-engineer-of-2020. Accessed 6 September 2012.
41. N. L. Fortenberry, Teaching the practical skills, *Mechanical Engineering Magazine*, December 2011, http://memagazine.asme.org/Articles/2011/December/Teaching_Practical_Skills.cfm. Accessed 6 September 2012.
42. D. Grasso, Engineering a liberal education, *Prism*, American Society of Engineering Education, **12**(3), 2002, p. 76.
43. S. Sheppard, S. Gilmartin, H. L. Chen, K. Donaldson, G. Lichtenstein, Ö. Eris, M. Lande and G. Toye, *Exploring the Engineering Student Experience: Findings from the Academic Pathways of People Learning Engineering Survey (APPLES)*, Center for the Advancement of Engineering Education, 2010, http://www.engr.washington.edu/caee/CAEE-TR-10-01%20APPLES%20v2.pdf. Accessed 6 September 2012.
44. C. J. Atman, S. Sheppard, J. Turns, R. S. Adams, L. N. Fleming, R. Stevens, R. A. Streveler, K. A. Smith, R. L. Miller, L. J. Leifer, K. Yasuhara and D. Lund, *Enabling Engineering Student Success*, The Final Report for the Center for the Advancement of Engineering Education, http://www.engr.washington.edu/caee/CAEE%20final%20report%2020101102.pdf 2010, Accessed 6 September 2012.
45. S. Haase, Engineering Student Survey Methods—working paper, forthcoming, www.cfa.au.dk
46. K. Donaldson, H. Chen, G. Toye and S. D. Sheppard, Targeting undergraduate students for surveys: Lessons from the Academic Pathways of People Learning Engineering Survey (APPLES), *Proceedings of the Frontiers in Education Annual Conference and Exposition,* Milwaukee, Wisconsin, 2007.
47. K. Donaldson, H. L. Chen, G. Toye, M. Clark and S. D. Sheppard, Scaling up: Taking the Academic Pathways of People Learning Engineering Survey (APPLES) National, *Proceedings of the ASEE/ISEE Frontiers in Education Conference,* Saratoga Springs, NY, 22–25 October, 2008.
48. M. Lehmann, P. Christensen, X. Du and M. Thrane, Problem-oriented and project-based learning as an innovative learning strategy for sustainable development in engineering education, *European Journal of Engineering Education*, **33**(3), 2008, pp. 283–295.
49. E. Otto, H. Chen and S. Sheppard, Students improving:

Identifying factors that seem to matter, conference paper, American Society for Engineering Education, 2010.
50. S. Brunhaver, S. Sheppard and O.Eris, Looking at engineering students through a motivation/confidence framework, *American Society for Engineering Education*, 2011.
51. R. Marshall and C. Lee, A cross-cultural, between-gender study of extreme response style, in B.G. Englis, and A. Olofsson (Eds.), *European Advances in Consumer Research*, Volume 3, Provo, UT, Association for Consumer Research, 1998, pp. 90–95.
52. A.-W. Harzing, Response styles in cross-national survey research: a 26-country study, *International Journal of Cross-cultural Management*, **6**(2), 2006, pp. 243–266.
53. D. De Vaus, *Surveys in Social Research*, 5th edn, Routledge, 2002.

Sanne Haase is a Ph.D. fellow at the Danish Centre for Studies in Research and Research Policy, Department for Political Science and Government at Aarhus University. She investigates engineering student conceptions of their future professional identity and role in the society.

Helen L. Chen, Ph.D., is a researcher in the Department of Mechanical Engineering and the Director of ePortfolio Initiatives in the Office of the Registrar at Stanford University. She earned her undergraduate degree from the University of California, Los Angeles and her Ph.D. in Communication with a minor in Psychology from Stanford University. Through collaborations with national and international portfolio researchers, she co-led the development of *Folio Thinking*, a reflective practice that situates and guides the effective use of learning portfolios. Dr. Chen's research interests are focused in three areas: academic and professional persistence in engineering education; the use of ePortfolios for teaching, learning, and assessment; and documenting and evaluating pedagogical innovations in technology-augmented learning spaces. Dr. Chen and her colleagues, Tracy Penny-Light and John Ittelson, are the authors of *Documenting Learning with ePortfolios: A Guide for College Instructors* (2011).

Sheri D. Sheppard, Ph.D., P.E., is professor of Mechanical Engineering at Stanford University. Besides teaching both undergraduate and graduate design and education related classes at Stanford University, she conducts research on engineering education and work-practices, and applied finite element analysis. From 1999 to 2008 she served as a Senior Scholar at the Carnegie Foundation for the Advancement of Teaching, leading the Foundation's engineering study (as reported in *Educating Engineers: Designing for the Future of the Field*). In addition, in 2003, Dr. Sheppard was named co-principal investigator on a National Science Foundation (NSF) grant to form the Center for the Advancement of Engineering Education (CAEE), along with faculty at the University of Washington, Colorado School of Mines, and Howard University. More recently (2011) she was named as co-PI of a national NSF innovation center (Epicenter), and leads an NSF program at Stanford on summer research experiences for high school teachers. Her industry experiences include engineering positions at Detroit's ″Big Three:″ Ford Motor Company, General Motors Corporation and Chrysler Corporation. At Stanford she has served as chair of the faculty senate, and is currently the Associate Vice Provost for Graduate Education.

Anette Kolmos is Professor of Engineering Education and PBL and Chairholder for UNESCO in Problem Based Learning, Aalborg University. She was also president of SEFI 2009–2011 (European Society for Engineering Education) and Founding Chair of the SEFI-working group on EER. During the last 20 years, Dr Kolmos has researched the following areas, primarily within Engineering Education: development and evaluation of project based and problem based curriculum, change from traditional to project organized and problem based curriculum, development of transferable skills in PBL and project work, and methods for staff development. She is Associate Editor for the *European Journal of Engineering Education* and was Associated Editor for *Journal of Engineering Education* (ASEE). She is a member of several organizations and committees within EER, national government bodies, and committees in the EU.

Niels Mejlgaard, Ph.D., is senior researcher and director at the Danish Centre for Studies in Research and Research Policy, Department for Political Science and Government at Aarhus University. His research interests include science policy and governance, public understanding of science, and university transformations. He has published on these issues in broad and specialized journals including *Nature Biotechnology, Science and Public Policy, Public Understanding of Science*, and *Science as Culture*. He has led several Danish and European research projects, including, recently, the Monitoring Policy and Research Activities on Science in Society in Europe (MASIS) project.