AC 2011-1053: PATHWAYS TO MALE-DOMINATED ENGINEERING PROGRAMS

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Pathways to Male-dominated Engineering Programs

Introduction

Finland is a country of 5 million people in the Northern part of Europe. According to a recent Canadian report[1], our country is considered equal in gender as well as other metrics measuring accessibility to higher education. However, despite the relatively equal access to our higher education, when it comes to students, we still suffer from clearly segregated female and male segments, i.e., education and liberal arts being most female-dominated and engineering male-dominated. Moreover, the engineering profession in general struggles with an unappealing image caused by the dot com collapse that reverberated in form of massive layoffs in the technology sector in Finland in 2002. After a few years, the global financial crisis worsened the tainted reputation of the higher engineering education associated with relatively limited job security. In order to face these problems looming ahead we are in a need of the most eligible candidates from both sexes in our degree programs. The long term view of our university statistics reveals that the proportion of accepted female applicants had a slight positive curve from 1990 (17,5 %) to 2001 (25 %), whereas the 2002 collapse caused a temporary downturn in the figures.[2] However, since 2005 the number of accepted female applicants has not increased and has been established at 24,5 %. The role of the dot com collapse or concern over job security is still only one factor that can be seen as a forcing one compared to the multitude of factors affecting the women's underrepresentation.

In the large scale the underrepresentation of women in engineering programs continues to be a world-wide phenomenon[3-5]. Some common reasons for women not to choose engineering are depicted to be lack of suitable role models[6], sex-stereotyped and/or negative view on science and scientists[7] and masculine content and climate of technical institutes[8]. The impacts of old-fashioned stereotypes are surprisingly strong not only in the traditional industry, but also in the field of ICT, where most girls drop out of the track latest after secondary school level: Even if girls enjoy studying ICT, most of them refuse to consider ICT as a career choice[9-11]. Earlier research[12, 13] emphasizes that family connections in the field of science, technology, engineering and math (STEM) have a positive influence on women's career choice. The importance of role models is commonly noted as another positive factor in recruiting process[6]. It should be noted, that the countries covered in our background comparison are limited to developed nations, thus leaving wider cultural considerations out of the scope of this paper.

In this study, we examine the pathways on which the female students land into some of the most male-dominated programs in our university. The approach for our study was to investigate the statistics covering the past four years in the largest engineering university in Finland and most importantly to review the results of a narrative inquiry conducted among the freshmen in three degree programs. In the analysis, the students wrote free-form narratives on how they ended up in the programs in question, what they considered as their strengths concerning the studies ahead, and what possibilities they saw in their engineering career in the future. The narratives were produced during the first weeks of study, capturing the first impressions as well as the pre-conceptions and expectations formed prior to the initiation of the studies. Traditional findings, namely identifying relatives in the field and natural sciences in general as sources of inspiration, hold with both male and female candidates. Our research question was to identify the pathways along which the rare females in the most male-dominated fields in our university arrive from secondary level school system. The answer to

this question is considered to be a key prerequisite for improving recruitment processes of our university.

Background

The Organization for Economic Co-operation and Development (OECD) has created a Program for International Student Assessment (PISA). The PISA is an assessment program for evaluating school systems in varying countries around the world. The PISA assesses how well the students near the end of compulsory education have acquired some of the knowledge and skills that are essential for full participation in society. In all assessment cycles, the domains of reading, mathematical and scientific literacy are covered not merely in terms of mastery of the school curriculum, but in terms of important knowledge and skills needed in the adult life. In the PISA 2003 cycle, an additional domain of problem solving was introduced to continue the examination of cross-curriculum competencies.[14]

Finnish secondary school system has always performed very well in the PISA evaluations. Our education system has proven to be both equal and of high-level quality. This is explained to be a continuum of our welfare society which covers basic aspects of a child's well-being from communal maternity clinics and daycare to esteemed communal elementary school system. However, our weakness is proven to be the conservative gender attitudes among teenagers aged 15: mathematics is for boys and reading is for girls. For the skill of reading, this is accurate: girls achieve substantially higher scores than their peer boys. However, in mathematics the margin is small. Even so, most of the PISA-aged girls are not interested in mathematics. They also suffer from a low self-esteem concerning their capabilities in natural sciences; even though they are talented in mathematics, their trust in their abilities is rock bottom. This phenomenon has strengthened in recent years.[15]

In the oldest and largest institution providing higher engineering education in Finland, the Aalto University School of Science and Technology, the proportion of females in freshmen is 24,5 %. The proportion of female freshmen varies from almost 50 % to mere 7 % between different degree programs. The traditionally most male-dominated degree programs are computer science, automation and systems technology and electronics. Valuing quality over quantity, some of the rare female students have been found to achieve relatively good study results compared to the majority of men. However, the study achievements of female freshmen vary greatly between the three investigated programs from fairly good to the unofficial 50 percent dropout rates during the first academic year.

Methodology

In this study we apply qualitative research in the form of narrative inquiry. The data collection method was simple: all new arriving students in our Aalto University School of Science and Technology wrote free-form stories about their pathways into the engineering fields. The minimum length of the essay was two A4 pages with font size of 12 pt at maximum. The deadline for the essay was set four weeks from the beginning of the semester. In that way, the first impressions of the initiated studies already reflected in the structure and content of students' essays.

All students were informed about possible research use with guaranteed anonymity of the contributing students. Students were also informed of their right to deny the usage of their material in which case the essay would not be used in the research. The instructions on how to

write the essay were purposely left open and wide-ranging. The guidance received by the students was to write a story about how they ended up in our university, what they considered as their strengths concerning their studies ahead and what future possibilities they see in their engineering career. In this study, we focus in the pathways to the studies. The more detailed, elaborate, non-compulsory questions to support a student's writing process were the following: What brought you to study here? How did you choose your study program? What did you know in advance about the field you have come to study in our university?

It should be noted that all of our degree programs in the university would have qualified for research of the reasons why secondary level school girls choose the highly male-dominated engineering fields. However, with the interest in the most problematic cases, the research was directed to scrutinize the most male-dominated degree programs: computer science, automation and systems technology and electronics. The proportions of female students in the researched degree programs are presented in the Table [1]. The reader should observe that the official numbers of students registered in the university are much higher than the number of students that actually begin their studies.

	All registered students	Female	Female percentage	...	N. o. males in the first introductory course	N. o. females in the first introductory course
Computer science	87	6	7 %		49	3
Automation and systems technology	61	6	10 %		38	5
Electronics	143	15	10 %		105	10

Table 1 demonstrates the proportion of female freshmen in three programs in question. In the table the number of registered students vs. the number of students in the first introductory course is presented. There is a notable difference between students registered and students participating in the first introductory course. This phenomenon is very typical to universities in Finland for three reasons: our higher education is mainly free of charge, a registered student gains social benefits and registering to more than one university is possible. The reasons for students missing from the first course fall most probably into the three categories presented above.

From the student population, a sample of 36 students was picked to our research. Because of the low number of female freshmen, we included them all into our sample. In that way, we collected 18 essays: three of computer science, five of automation and systems technology and ten of electronics degree programs. For a peer group we collected 18 essays of male freshmen. To get a more descriptive sample we collected six freshmen from each degree program. The difference in sampling is taken into account in analysis and results.

In this research, the theoretical perspective of narrative inquiry was used: In a wide sense, narrative research refers to any study that uses or analyzes narrative materials.[16] The essays that the students wrote fulfilled the definition of narratives: The essays contained an initial state, a story line (a continuum of experiences) and a conclusion.[17] The initial state was the first recollection of an idea for engineering studies. The story line was the chain of events, which affected one another (consequences) and eventually lead to the conclusion (final state). A conclusion (final state) was the settlement into faculty in the beginning of studies. First, the students' story lines were compressed to highlight the essential material. After a careful

analysis, connective categories and themes were found. The themes are documented in the results section. Each quotation is cited as male student [n] or female student [n].

Results

The most influential connective factor between all candidates was the traditionally found theme of friends or relatives in the field in question[9,12]: Both female and male students were intrigued by the work or study fields of relatives or acquaintances. Most of the students didn't describe any technical conversations, but they seemed to rely on the thought that 'if this works for them, it suites me as well'. We cite female student [1].

> Female student [1]
> …" I do not have any particular reason to study here. I thought of Aalto University School of Science and Technology as an option in secondary school level. One reason for me to apply here was that my father has a M.Sc. in technology and he persuaded me to higher level engineering studies. He also had a strong opinion of the importance of STEM studies in secondary school level."…

We cite a male-student [1], who had both relatives in the field and technology interest as quite major factor.

> Male student [1]
> ." Since a little boy I have shared the interest in all technology. Later on this has led me to hobbies and summer jobs in the field of <degree program name>. Also in my family I have several technically educated relatives and successful entrepreneurs. " ...

Majority of male students had been interested in technology since childhood and had hobbies in the field. The phenomenon doesn't apply to the female students: only one of 18 female students was interested in technology. Nor did the majority of women have any technology-related hobbies or working experience. Mathematics was a substance that female freshmen valued clearly over their male peers: Engineering studies attracted many women, because of the possibility to apply mathematics into other subjects. We cite female-student [2], who has a typical view on mathematics and choice of one's study field.

> Female student [2]
> … "Since I have always enjoyed mathematics, I wanted to take advantage of it in my studies. However, I didn't want to study theoretical mathematics, so I found quite appealing the thought of applying mathematics in engineering education."…

Overall, the female applicants were talented in many ways, and also had interests in many areas outside engineering. Our degree programs were clearly not the only or not even the first choice for them. The female freshmen had substantially more often started their studies in their second, third or even fourth choice compared to their male peers, who mostly were in their first choice degree program. The most common interests for the women, beside our School of Science and Technology, were in Faculty of Medicine, School of Economics and Faculty of Science. The research draws a picture of multitalented young women, who have

many opportunities for university level studies and who happen, for some reason, to land in our programs.

> Female student [3]
> …"At some point of the senior year in high school, I simply decided that I will become a medical doctor or an engineer. I didn't know which I'd like better or did I like either actually, but a decision had to be done and I applied for both."…

It is also interesting that there can be seen a tendency that majority of male students decide their preliminary plans for future earlier than female peers. Over a half of the sample group women, who covered the issue in their narratives, wrote that they had started the decision making process concerning their future earliest during earliest the last two years before matriculation: females appear to keep other options open until they are either forced to decide or drift into the field of technology. Only two of the male students had left the decision this late, most of the male candidates showed early orientation towards engineering studies. It should be noted that it is quite common in Finland to leave the decision of applying for higher education institutes quite late in secondary level studies. On the other hand, to be eligible candidate in higher level engineering studies, one has to choose STEM subjects in secondary level.

The decision of the degree program was hard work for many of the applicants. A group of the applicants spent hours reading all kind of prospective students' material, some of them attended stands or lectures in recruiting events. Even though careful examination, some basic generalizations and even some misconceptions took place: majority of male students in automation and system technology had chosen the field because 'they would learn robotics in there', which is quite a common perception even if robotics is just a part of the field. One female student came to learn electronics with an objective to 'get to know how to construct kitchen aids'. Large proportion of female students didn't examine the possibilities of studies thoroughly. Instead, they chose their degree program by the intuitive thoughts raised by a short description or a few individuals even by only the terms in the given programs' titles. We cite a female student [4] as an example of a loosely selected study program.

> Female student [4]
> ..."<the study program name> was my first choice of study field, even though I hadn't and still do not have a clue, what I am supposed to study here. A Master of Science degree is appealing because it can provide diverse, international and a wide scale of opportunities in working life"…

One popular method for female applicants to choose their degree program was to strike out the degree programs that felt uninteresting and then line the rest up. Hereby we present an example of a female student [5].

> Female student [5]
> .." I chose my degree program in a quite random way. I didn't know what would interest me more than others. I discarded the ones I didn't want to study, which was a good idea, because I managed to come up with a few. I didn't know how to put them in order, though. I chose the one I momentarily felt the best and I ended up in the <degree program name>-degree program, which seemed a good study field."...

Another noteworthy phenomenon could be described as a positive form of cognitive dissonance. Even if half of the female students started their studies in a program other than their first choice, they described the beginning of their studies and the degree program with very positive and emotional expressions as opposed to logical or analytical deduction. Despite their original thoughts, they seemed very happy with their choice. A female student [6] was extremely disappointed because she did not get in to the degree program she wanted. Still, she writes about the great teaching in her secondary choice program:

> Female student [6]
> ..." I have studied in <degree program> for three weeks now, and I have realized that I definitely will not change my degree program in the future. I don't know what my competences will be in five years. Most important thing is that I'm interested in what I do now. The subjects are interesting and I'm motivated. "...

Statistics and beyond

The Bologna process started in 1999 by declaration, which stated as targets the adoption of a system of readable and comparable degrees based on three cycles, bachelor and master level (undergraduate) as well as doctoral (graduate). The countries involved in this reform agreed to follow similar objective study times: three years for bachelor and additional two years for master level studies. Then European Credit Transfer System emerged. Bachelor's degree consists of 180 credits, master's degree 120 credits. The ideal study objective is 60 credits (ECTS) per study year.[18] In Finland, these study objectives haven't materialized in technical universities.

In the three tables below, we examine the progress of studies and dropping out figures of women in our three degree programs. Our assumption is that the ideal study objectives are not likely to be met. Therefore, we use another factor for measuring the actual study process: we consider a person to be still actively studying, if the amount of her credits is at least half of the targeted credits.

The data is based on study record statistics of all women in the three programs from 2006 to 2010. First column (Years studied) states how many years the students have studied. Second column (Target) presents the credit targeted in this time period to meet the ideal study objectives. The third column (On target) presents the percentage of women, who have met the Bologna process ideal study objectives.

Fourth column (Studying) presents the percentage of women, who appear to be actively studying, reaching at least half of the study objective credits. The fifth and last column (Dropout) indicates the percentage of women who seem to have dropped out during the time period. The last item is difficult to measure in Finland, because many of the students enroll to the university even after they have interrupted their studies to get the social benefits and subsidies available to students. However, we interpret a student having interrupted her studies, if the number of acquired credits is lower than half of the ideal credits, which would imply the timeline for bachelor's degree to be more than six years. We presented the female students' study achievements in our three study programs Computer science (Table [2]), Automation and systems technology (Table [3]) and Electronics (Table [4]).

Computer science

Years studied	Target	On target	Studying	Dropout
1.	60	20 %	40 %	40 %
2.	120	29 %	71 %	0
3.	180	11 %	56 %	33 %
4.	240	0 %	71 %	29 %

Table 2 shows the variation of female students' study success in the department of Computer Science study program. Minority of students meet the Bologna process targets. The dropout rates vary from 0 to 40 %.

Automation and systems technology

Years studied	Target	On target	Studying	Dropout
1.	60	0 %	100 %	0 %
2.	120	0 %	67 %	33 %
3.	180	0 %	100 %	0 %
4.	240	0 %	80 %	20 %

Table 3 shows the study rates of female students in Automation and systems technology program. The column "Target" indicates that the Bologna process study objectives are not met, but majority of students are still on track to graduation (Column "Studying").

Electronics

Years studied	Target	On target	Studying	Dropout
1.	60	6 %	56 %	39 %
2.	120	8 %	58 %	33 %
3.	180	10 %	45 %	45 %
4.	240	0 %	50 %	50 %

Table 4 shows the study rates of female students in Electronics department. The table presents that dropout rates are high, at the utmost 50 % of students. Depending of years studies, 50-66 % of students are still on track towards graduation (either on target or studying).

Discussion

In the light of our research, it seems that women, who start their studies in one of the most male-dominated programs, Computer science, Automation and systems technology and Electronics, in our Aalto University School of Science and Technology, are intelligent and talented enough to perform well in the engineering studies. However, female students often lack the preceding experience and familiarity with technology compared to their male peers. Most women find their way to these programs based on their enthusiasm for mathematics. Even though this might be beneficial at the beginning of the studies, when mathematics has more emphasis in the study schedule, the inherent motivational problems might manifest

themselves with the beginning of actual vocational subjects. There is a tendency of quite high drop-out rates (up to 50 percent).

On the other hand, the women starting in our degree programs had applied for more study alternatives compared to their male-peers. Whereas most of the male students had planned for an engineering career for years, for the female students, the choice of a field is done in a quite late phase – and the engineering program was not the only or even the first choice. We hypothesize with the possibility that their professional identity may be in early stages of forming, rendering studies to be easily interrupted due to other distracting opportunities that they may come across.

From the curriculum point of view, one adjustment to encourage women to apply into degree programs and to keep them there could be to offer the students more interdisciplinary study content. This could broaden the study possibilities in our university in order to strengthen the commitment into engineering studies. This should be seen as an investment, not only for a student retaining process, but also improving the students' competitiveness in the ever-changing technical discipline: the future workforce should be equipped with broader skill set and application capability than mere traditional technical expertise.

When thinking about the recruitment process for these young women, we contemplate actions timed in the secondary education phase. According to our research, the decisions are made within a relatively short time period before matriculation (and applying for higher education). We propose that during this time period visible positive role models could draw girls into technology. The flip side of the coin is equally important, as there appears to be a student segment with completely unreal expectations of the technology- oriented careers. These individuals could spare their and university's time and resources by reassessing their future prospects against realistic examples provided by the role models in the area of technology before applying.

For the fact that relatives have the most impact when choosing an engineering career, we could hardly contribute. On the other hand, not all young women attracted to the technology do so because of relatives in the field.

Conclusions

We conclude that becoming a female student in male-dominated engineering programs is a relatively overwhelming yet a rewarding process. Our findings support the assumption that there are certain differences between sexes in the pathways to higher engineering education. We present the differences to be in the very basic reasons of why students choose their future occupation. However, it is to be remembered that our findings tend to describe the common trend, while individual differences should be taken into account when taking a closer look of certain factors.

Male candidates were primarily keen on technology whereas the female peers valued mathematics. Noteworthy finding in our study is that the majority of female freshmen did not choose their fields on the account of facts but instead on the intuitive thoughts raised by the terms in the given programs' titles or a short description. Even though many of them started their studies with joy and enthusiasm (somewhat contrary to their male peers), this might very well be at least a partial reason for high dropout rates in certain programs. Based on these findings, we argue that it would be prudent to take a closer look on the recruitment

procedures. Moreover, the challenge in recruiting is to strike a balance: How to create a realistic, and at the same time appealing, picture of a profession, which would attract these women into engineering.

[1] Usher, A. & Medow, J.: "Global Higher Education Rankings 2010: Affordability and Accessibility in Comparative Perspective", October 2010, http://higheredstrategy.com/publications/GHER2010_FINAL.pdf (retrieved 8 March, 2011)
[2] Paloheimo, A., Leppävirta, J., Hyytiäinen, M. and Putila, P.: "Managing the challenges -introducing the female minority in technical research society", Proceedings in SEFI and IGIP Joint Annual Conference, Miskolc, Hungary (2007).
[3] Gill, J., Sharp, R., Mills, J. and Franzway, S.: "I still wanna be an engineer! Women, education and the engineering profession", European Journal of Engineering Education, Year 2008, Vol. 33, No. 4, August, Pp. 391-402(12).
[4] National Science Foundation (NSF) "Women, Minorities, and Persons with Disabilities in Science and Engineering", Arlington, VA | NSF 11-309 | February 2011 http://www.nsf.gov/statistics/wmpd/ (retrieved 8 March 2011)
[5] Jhon, G., J., Hee, L., S. and Lee, K., W.: "Advancement of women in science and technology: A case study of Korea", Ewha Womans University Press, 2006.
[6] Brown, B. L.: "Women and minorities in high-tech careers", ERIC Clearinghouse on Adult, Career, and Vocational Education, Center on Education and Training for Employment, College of Education, the Ohio State University, 2001.
[7]European Comission Report: "Science Policies in the European Union - Promoting excellence through mainstreaming gender equality", http://ec.europa.eu/research/science-society/pdf/g_wo_etan_en_200101.pdf (retrieved 08 March 2011)
[8] Sagebiel, F. and Dahmen, J.: "Masculinities in organizational cultures in engineering education in Europe: results of the European Union project WomEng", European Journal of Engineering Education, 1469-5898, Vol., 31, Issue 1, 2006, Pp. 5 – 14.
[9] Miliszewska, I. and Moore, A.: "Encouraging Girls to Consider a Career in ICT: A Review of Strategies", Journal of Information Technology Education, Year 2010, Vol. 9.
[10] Gras-Velazquez, A., Joyce, A. and Debry, M.: "Women and ICT Why are girls still not attracted to ICT studies and careers?", White paper developed for European Schoolnet (EUN Partnership AISBL), 2009. http://newsroom.cisco.com/dlls/2009/ekits/Women_ICT_Whitepaper.pdf (retrieved 08 March 2011)
[11] Anderson, N., Lankshear, C., Timms, C. and Courtney, L.: "'Because it's boring, irrelevant and I don't like computers: Why high school girls avoid professionally-oriented ICT subjects", Computers & Education, Year 2008, Vol. 50, Num. 4, Pp. 1304-1318.
[12] Buzzetto-More, N., Ukoha, O. and Rustagi, N.: "Unlocking the Barriers to Women and Minorities in Computer Science and Information Systems Studies: Results from a Multi-Methodolical Study Conducted at Two Minority Serving Institutions", Journal of Information Technology Education, Uear 2010, Vol. 9.
[13] Adya, M. and Kaiser, K. M.: "Early determinants of women in the IT workforce: a model of girls' career choices", Information Technology & People, 2005, Vol. 18, Num. 3, Pp. 230-259.
[14] OECD Programme for International Student Assessment (PISA), http://www.pisa.oecd.org/ (retrieved 8 March, 2011)
[15] Finnish Ministry of Education and Culture, http://www.minedu.fi/OPM/?lang=en (retrieved 8 March, 2011)
[16] Lieblich, A., Tuval-Maschiach, R., Zilber, T.: 'Narrative Research. Reading, Analysis and Interpretation.', Applied Social Research Methods Series, 1998, Vol. 47. Sage Publications: Thousand Oaks.
[17] Clandinin, D., J. and Connelly, F., M.: "Narrative Inquiry: Experience and Story in Qualitative Research", San Francisco: Jossey-Bass Publishers, 2000.
[18] The Bologna process; A European reform process aimed at creating the European Higher Education Area. Information about the process: http://www.ond.vlaanderen.be/hogeronderwijs/bologna/about/ (retrieved 8 March, 2011)