Reaching out for girls

Raising interest and self-efficacy in engineering with 'girls only' workshops at a technical university

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ABSTRACT

The paper presents an outreach activity targeted for elementary school girls to increase their interest and self-efficacy in technology and engineering. The activity consisted of visits to a technical university with two to four workshops on different

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science and engineering topics per visit. Five visits in total were organised for different girl groups during the year 2017 with 104 girls attending the activity.

The workshops were designed based on previous experiences and research findings about relevant topics and formats of activities. The workshops were made as interactive and practical as possible, and the topics and activities were connected with the girls' experience and spheres of life. The visits were offered exclusively for girls to prohibit the typical effect of boys on girls' behaviour in situations of this kind. Providing room for positive peer role models aimed at empowering girls by generating shared experiences among participants.

The participants were asked to rate their interest towards engineering/technology and their self-efficacy in engineering subjects before and after the visit. They could also make open comments about the workshops and the visit in general. The analysis revealed that the changes in both perceived interest and perceived self-efficacy were positive and statistically significant for the whole population and the smaller groups although there were differences between the groups both in the magnitude and significance of the change. Both quantitative and qualitative data seem to verify the original design principles and assumptions on what makes an outreach activity for girls interesting and efficient.

1 INTRODUCTION

The under-representation of women in technical studies and vocations is a well-known and cross-national phenomenon (see e.g. Joyce & Dzoga 2013, National Science Foundation 2018, Buccheri, Gürber & Brühwiler 2011). It has been found that even when females have the same competences in science as males, they avoid vocational choices such as being engineers or technicians (Buccheri et al. 2011). This has been explained for example with women's greater interest in people than things (Su & Rounds 2015), the mismatch between girls' self-image and the image they have of engineering-related subjects such as physics and mathematics (Taconis & Kessels 2009, Kessels 2015, Makarova & Herzog 2015), the influence of socializers, such as teachers, parents, or peers (Ikonen, Leinonen, Asikainen & Hirvonen 2017, Riegle-Crumb & Morton 2017), and the girls' fewer technology-related experiences in childhood and primary education (Niiranen 2016).

Along with the multitude of possible explanations for the gender disparity in engineering there is a wide selection of suggestions for ways of correcting the situation (Blickenstaff 2005). Henwood (1996) argues that many of the initiatives to get more women in engineering focus too narrowly on women's choices and attempt to solve the problem by changing women, i.e., giving them more information or trying to change their image of the field, and leaving the structures and culture of the field intact. Although it is undoubtedly true that changing only the communication resembles delivering 'fake news', which is more likely to make the situation worse than better, giving the girls better opportunities to experience and access the world of technology and engineering is at the heart of many outreach activities aiming to decrease the gender disparity in the field. This should, however, not be seen as merely transmitting information – as at least the Finnish girls state that they are aware of the relevance of STEM subjects to their life (Microsoft 2017) – but more as a chance for girls to get personal experiences, and an opportunity to form an opinion based on themselves instead of hearsay or media images.

The outreach activities created to attract more girls in engineering come in different forms. They range from short workshops and day visits (e.g. Weston, Bonhivert, Elia, Hsu-Kim & Ybarra 2008, Molina-Gaudo, Baldassarri, Villarroya-Gaudo & Cerezo 2010) to longer projects (Ward, Lyden, Fitzallen & de la Barra 2015) to camps (Todeschini & Demetry 2017). They may be for girls only (Egbue, Long & Ng 2015, Weston et al. 2008) or also include boys (Jahan & DeJarnette 2014, Ward et al. 2015). Some aim at delivering specific contents to the participants, such as knowledge on electric vehicles (Egbue et al. 2015), whereas others focus on the engineering design process (Ward et al. 2016) or introduce engineering work and subdisciplines (Weston et al. 2008, Molina-Gaudo et al. 2010). Participants often come to campus, but sometimes the activities are brought to the participants for example with specifically equipped vehicles (Jahan & DeJarnette 2014).

Activities commonly show positive short-term impacts, but the research on the long-term impacts is unfortunately scarce. Todeschini and Demetry (2017) have conducted two longitudinal studies, which indicate that outreach activities may have a positive long-term effect on girls' intentions to study engineering, their perceptions of engineers, and sense of empowerment and self-confidence. The short-term effects are well in line with these. Molina-Gaudo et al. (2010) reported that a 'Girls' Day' improved slightly the motivation to pursue engineering careers and changed gender-biased views of the profession. Jahan and DeJarnette (2014) discovered that a mobile programme for enhancing engineering education increased participants' interest to become an engineer, and Egbue et al. (2015) concluded that after a workshop on electric vehicles the students had a clearer understanding of the engineering profession. Quite interestingly, using engineering activities to engage middle school students in physics and biology increased female students' interest in physical science but did not change male students' interests in biological science (Ward et al. 2015), and the hands-on type of activities increased girls' interest, knowledge and confidence in engineering notably more than in mathematics or science (Weston et al. 2008).

2 METHODS

The aim of the outreach activity was to increase girls' interest and self-efficacy in technology and engineering. The activities had to be designed in such a way that they could be used for groups of different sizes and participants of different ages, and conducted in slightly different time frames. The objective of the study was to discover the short-term impacts of the activity and thereby evaluate the effectiveness of the activity, but also understand what is essential in designing and executing outreach activities of this kind.

2.1 Design and execution of the activity

The first decision to be made was to target the outreach activity exclusively at females. Male peers with explicit gender/STEM stereotypes have been noted to significantly and negatively affect girls' intentions to pursue technical careers (Riegle-Crumb & Morton 2017). Girls also tend to get less time and attention compared with boys in a mixed STEM classroom with both genders taking this as a natural state of affairs and feeling unpleasant if the situation is changed (Paloheimo 2015). Thus, it was perceived that having no boys in the activity would enhance the girls' activeness and experience.

The original idea was to find groups that naturally consist only of girls, e.g. Girl Scouts, so that the whole group could be invited and nobody (i.e., the boys) would feel left behind. However, this proved to be challenging for many reasons, particularly timing (hobby groups could not easily book a school day for girls coming from many different schools, and the university laboratories were not available during weekends and holidays). In the end, there was only one Girl Scout group among the visitors. Fortunately, local schools were willing to collect girls only groups to come to the campus for a day.

In order to have the needed flexibility, it was decided to construct the activity to consist of a short introduction and a flexible number of different workshops. The workshops were designed based on earlier experiences of visiting child and adolescent groups and research findings, and suggestions found in the literature. A special effort was made to incorporate as many hands-on activities as possible, as they have proven to be effective (Weston et al. 2008) and longed for in the STEM teaching by Finnish girls (Microsoft 2017). Another focus was on connecting the activities with the girls' spheres of life. For example, Arduino programming was demonstrated with the use of sewable electronics, as Finnish girls are much more often familiar with textile than technical craft (Niiranen 2016), and the more traditional physics and electronics problems were connected with the fashionable escape room concept.

Each visitor group was given a short presentation about the university and careers in technology, and the group attended two to four of the following workshops:

Physics: In the physics laboratory, the girls were shown some phenomena e.g. in optics and magnetics, and they could test some of the phenomena themselves.

Arduino programming: Each girl practiced to connect a LED onto a circuit board and program it to blink at desired intervals. Some advanced to implement traffic lights with red, yellow, and green LEDs. The blink programme could also be tested with a LilyPad implementation (a badge with LED lights) to show how electronics and programming can be combined with handicraft. In the beginning of the workshop the girls were shown a brief video with different examples if LilyPad-use in everyday settings. This was hoped to stimulate the girls' thinking of possible personal use of the technology at hand.

Wind mill simulation: Girls built their own miniature wind mills, and then measured the amount of electricity produced by the mill attached to a miniature generator, using a table fan for wind. The activity was organised as a competition, where teams with the highest production volume were given small prizes.

Chemistry: In the chemistry laboratory, the girls used indicators to identify different solutions. Further, balloons were filled by using the reaction of vinegar and baking soda.

Escape room in electrical engineering: The “pop up” escape room contained tasks related to electrical engineering, with solutions that gave codes for locks. In the locked bags or boxes, new tasks were discovered, until the students found a key to “escape”. The tasks contained mathematical calculations tailored for the level of the visitors, and the person responsible for the escape room gave hints when needed. The workshop was conducted by a female post-doctoral researcher in electrical engineering, who was also acting as a role model of a woman with a successful career in technology.

The workshops lasted 30–60 minutes depending on the topic and the size of the group.

2.2 Collection and analysis of data

The participants were asked to evaluate their perceived interest in engineering/technology (vertical axis) and their perceived self-efficacy in the subject area (horizontal axis) by marking an ‘x’ in the coordinate system at the beginning of the visit, and an ‘o’ at the end. The coordinate system is illustrated in *Fig 1*.

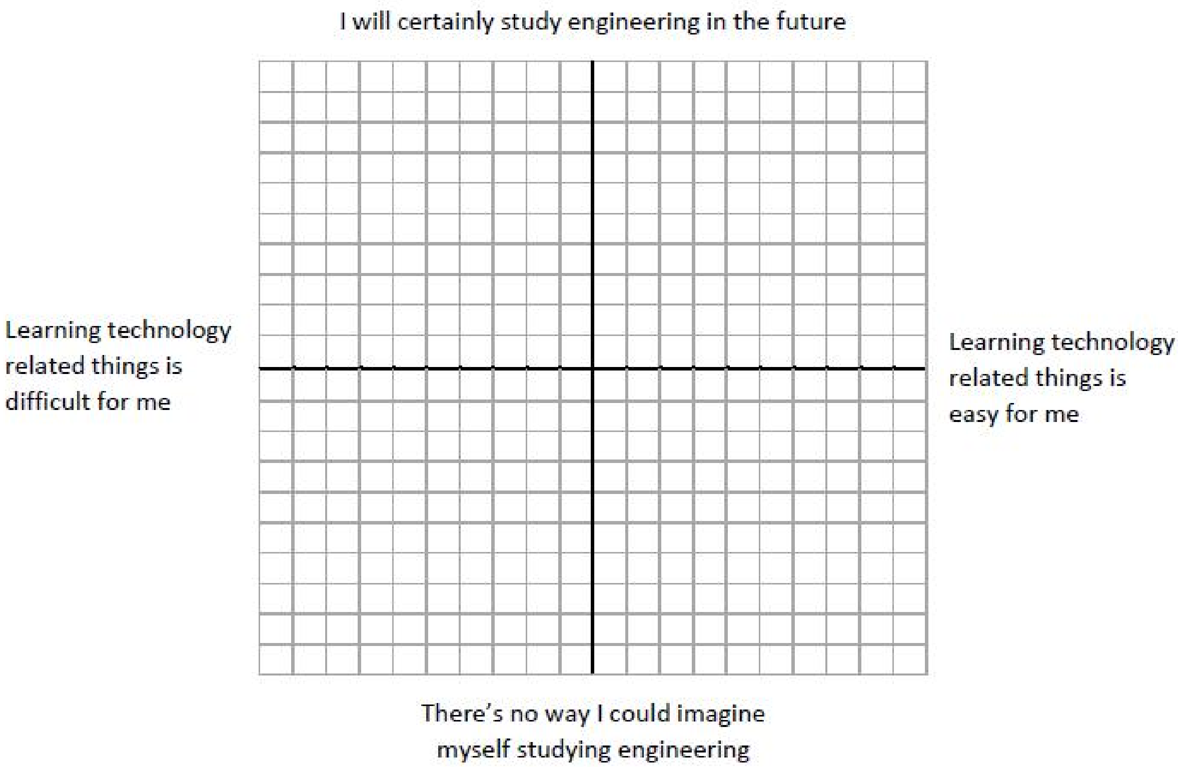

Fig 1. Coordinate system to evaluate one’s interest and self-efficacy in engineering/technology

As the visits started and finished in the same room, the participants could leave their form on the table, and no names or other identification were needed. In addition to the coordinate system, the questionnaire contained the following open questions, which were answered after the workshops:

- What did you find interesting/nice during the day?
- What did you find boring/unpleasant during the day?

The coordinate system was chosen in order to have the minimum number of questions and to direct the participants to think about their interest in relation to self-efficacy but also in relation to change in both aspects (did one change more than the other).

The filling of the form was instructed and illustrated with examples both at the beginning and at the end of the visit. Despite this, some answers could not be interpreted or considered reliable and were thus omitted from the analysis. After the visit, the forms were collected and the values were entered in an Excel sheet. When all the visits were over, the data were transferred to the statistical software Stata for analysis.

In Stata, the means and standard deviations for the pre- and post-activity evaluations as well as for the change, interest and self-efficacy were calculated for the whole group and for the different visitor groups. The significance of the change was examined with the paired samples t-test, and the differences between the two variables were investigated with the mean comparison t-test for unequal variances. The answers to the two open questions were grouped and analysed qualitatively.

3 RESULTS

Between April and November 2017, a total of 104 girls visited the campus:

- April 28th 2017: 16 seventh graders (age 13) from local school A
- June 7th 2017: 14 girl scouts of different ages
- September 28th 2017: 43 ninth graders (age 15) from three different schools in the neighbouring town
- November 9th 2017: 15 fifth graders (age 11) from local school B
- November 30th 2017: 16 seventh graders (age 13) from local school A (new batch compared with the group that visited in the spring)

For each group, workshops suitable for the age of the students were prepared and organised with a schedule agreed upon with the teachers. The combination of workshops for each of the groups is given in *Table 1*.

Table 1. Combination of workshops for different visitor groups

	Workshops				
Group	Physics	Arduino programming	Wind mill simulation	Chemistry	Escape room
7th graders from school A I		x		x	
Girl scouts		x	x	x	
9th graders from town X	x	x		x	x
5th graders from school B		x	x	x	
7th graders from school A II	x	x	x		x

Interpretable and reliable answers to the questionnaire were received from 96 participants. In most of the groups there was one questionnaire left unfilled or filled insufficiently (e.g. the same markings for the beginning and the end, or too many markings), but in the girl scout groups all of the youngest respondents (N=5) were left out as it was unclear whether they fully understood what they were expected to do. The means of the pre- and post-activity evaluations for both variables and all groups are presented in *Table 2* and illustrated in *Fig 2.*

Table 2. Participants' pre- and post-activity evaluations of their interest and self-efficacy in engineering/technology

		pre-activity evaluation		**post-activity evaluation**	
Group	**N**	**future in eng (mean)**	**easiness of tech (mean)**	**future in eng (mean)**	**easiness of tech (mean)**
7th graders from school A I	15	-0.1	1.0	4.3	2.3
Girl scouts	9	0	1.2	4.9	3.4
9th graders from town X	43	-0.3	-0.2	0.8	1.2
5th graders from school B	14	1.0	1.9	3.6	3.6
7th graders from school A II	15	-1.5	-0.7	1.5	1.8
All respondents	**96**	**-0.2**	**0.4**	**2.3**	**2.0**

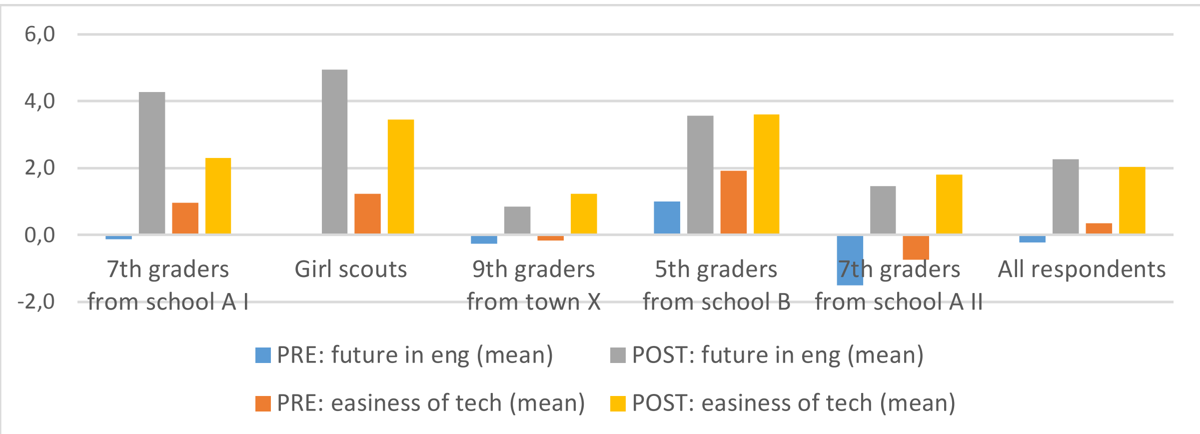

Fig 2. Participants' pre- and post-activity evaluations of their interest and self-efficacy in engineering/technology

The participants' pre-activity evaluation estimates for interest (future career prospects) and self-efficacy (perceived easiness) for the whole group were close to zero as can be expected with this kind of a measurement instrument (symmetric scale with zero in the middle) and the group of informants (rather large N and not expected to be biased in any direction). Although the mean of the pre-activity evaluation value for interest was slightly lower and the post-activity evaluation value slightly higher than for self-efficacy, the differences were not statistically significant (p=0.3563 for the pre-activity evaluation and p=0.7118 for the post-activity evaluation).

The change between the pre- and post-activity evaluation of both variables was, however, statistically significant for the respondents in total and for almost all of the groups separately. The means, standard deviations and the two-tailed p-values of the paired samples t-tests are collected in *Table 3*.

Table 3. Change in the participants' perceptions of the interest and self-efficacy in engineering/technology

	Change in future in engineering			**Change in easiness of technology**			**Mean comp. t-test**
Group	**mean**	**stdev**	**p**	**Mean**	**stdev**	**p**	**p**
7th graders from school A I	4.4	2.67	0.0000	1.3	2.13	0.0293	0.0018
Girl scouts	4.9	3.84	0.0048	2.2	3.07	0.0619	0.1175
9th graders from town X	1.1	3.65	0.0512	1.4	1.88	0.0000	0.6704
5th graders from school B	2.6	2.22	0.0008	1.7	2.81	0.0437	0.3599
7th graders from school A II	3.0	3.82	0.0095	2.5	4.43	0.0439	0.7764
All respondents	**2.5**	**3.61**	**0.0000**	**1.7**	**2.68**	**0.0000**	**0.0785**

For all respondents, the change in both perceived interest in engineering and perceived self-efficacy was statistically highly significant ($p<0.001$). With most of the visitor groups, the mean change in interest was larger than the mean change in self-efficacy, the ninth graders being the only exception. Yet, the only group where the difference between the magnitude of change is statistically significant was the first group of seventh graders (mean change in interest > mean change in self-efficacy, p= 0.0018). The only changes with no statistical significance were in the girl scouts' perception of the easiness of technology ($p=0.0619 > 0.05$) and the ninth graders' interest in engineering ($p=0.0512>0.005$).

The open comments revealed that each of the workshops had their lovers and loathers. To the question regarding unpleasant things, some comments connected "just watching" or "just listening" with becoming bored. In general, the younger visitors seemed to like chemistry best and the older ones preferred programming or the escape room. Many respondents stated that everything was nice and nothing was boring.

4 CONCLUSIONS

The results support the findings from previous studies that these kinds of outreach activities have at least short-term positive effects on the girls' interest and self-efficacy in engineering/technology. It seems, however, that the interest is more easily triggered at the younger age, as suggested also by Molina-Gaudo et al. (2010).

Hands-on activities appear to be effective regardless of the topic and the age group. This poses a challenge for the design of the workshops as the challenge level of the activity needs to be adjustable. Too difficult tasks are unlikely to promote self-efficacy whereas too easy tasks are perceived boring and uninteresting. Even though female students wish for more practicality to the STEM teaching in general (Microsoft 2017), it can be considered especially important when introducing students to engineering, as the creative nature of engineering work often remains invisible to the adolescents (Capobianco et al. 2011).

Connecting the new experiences with girls' world spheres was done primarily through the Arduino programming and escape room workshops. In the former girls were helped to get ideas of possible personal use of employed technologies through a video of examples and a physical demonstration. The latter was designed in the format popular from the leisure activities and conducted by a potential role model. Both workshop were among the most liked ones among the older visitors.

Perhaps somewhat surprisingly, there were no comments in the questionnaires regarding the exclusion of boys from the activities. One piece of anecdotal evidence was received from the mother of one of the participants, who had asked her daughter about this and got the following answer: "It was good that they weren't there to mess things up." Although this is of course only a single comment, it would be worthwhile to look more closely at this issue for instance by observing the dynamics of the mixed visitor groups.

All in all, the outreach activity was a pleasant experience for both the participants and the organisers. As the gender disparity of engineering is a long-term and, to some extent, even stagnant problem, these kinds of activities will be necessary also in the future. More knowledge is still needed especially of the long-term effects of these activities, and this should be taken into account when designing and executing future outreach projects. One encouraging weak signal of the longer-terms effects was received in April 2018, when two of the visitors presented a project in a local science festival and stated that they had received the spark and idea for their project from one of the visits described in this paper.

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