

DESIGN THINKING AS AN OUTREACH ACTIVITY FOR FEMALE STUDENTS

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ABSTRACT

There is widespread recognition of the need to attract more students, and female students in particular, to engineering study in Ireland, with many third level institutes and professional bodies actively engaged in outreach activity. This paper examines hypotheses that the role of design and creativity in engineering is under-recognised, while design based outreach is a powerful tool to attract potential students, and furthermore that the recognition deficit and potential benefits are larger for female students. A user-centred design activity was undertaken with a group of 16 and 17 year old girls as part of an engineering summer camp. Structured questionnaires were completed by both the participants and by activity demonstrators – undergraduate students in the 20-22 year old age bracket. Feedback from both cohorts suggests that such activities have a transformative effect on the attitudes and sense of empowerment of the potential students.

KEYWORDS: Outreach, Engineering, Design, Design Thinking, Gender.

INTRODUCTION

It has been estimated by Engineers Ireland that a 6-7% annual increase in the number of graduating engineers is needed to meet demand in the Irish economy by 2020, a requirement that proves to be “very difficult in the current climate of falling numbers of entrants to third-level courses in engineering and IT” [1]. Concurrently, there is an under-representation of female students in 3rd level engineering programmes. According to a gender report published by the Central Statistics Office [2], only 17% of graduates in engineering, manufacturing and construction courses, for the year 2011, were women. This is despite female students outperforming male students with regard to university entrance selection. The Central Statistics Office found that 7.85% of female Leaving Certificate students in 2011 received a minimum of 6 grade C3s on higher papers of which 3 or more were grade A2s or above whereas there was only 5.52% of male students who managed the same [3]. Successful initiatives to specifically target female students could improve the gender ratio (with concomitant benefits that increased diversity of the student base can bring [4]).

The tendency for women to avoid engineering courses at third level is fuelled, at least in part, in secondary school where the Leaving Certificate subject uptake shows significant gender imbalances with large and consistent inequality in the gender ratio of students studying higher level maths, physics, applied maths, construction studies and other subjects associated with engineering [5, 6]. Although studies show that not all of these subjects are significant indicators of a student’s likeliness to succeed in engineering [6], they do, at least, provide some exposure to, and grounding in, technically cognate (to engineering) disciplines.

Within engineering, several disciplines attract proportionately more women than others. According to results of the EU FP7 project ATTRACT, “there is a considerable tendency for *female students* to be concentrated in biological and chemical strands of engineering, while they generally remain significantly under-represented in physical, civil, computer and mechanical engineering programs”[7]. This could also be associated with Leaving Certificate subject choice – e.g. in 2011, the amount of female students that

sat higher level physics for the Leaving Certificate was 1,320, whereas chemistry and biology had 3,529 and 14,267 higher level students respectively.

Various methods of recruiting new engineering students have been explored in many countries with activities ranging from individual school talks to week long promotions such as Engineers Week in Ireland and cover a large range of engineering topics. Events during Engineer's week can incorporate design activities and the amount of students these activities reach can be considerable. STEPS, an initiative set up by Engineers Ireland, runs activities that can reach up to 75,000 primary and post primary students per year [8]. There are often design activities included in these outreach events such as the Formula 1 Technology Challenge held by the Irish Computer Society (ICS) where students design a compressed air powered car. Probably due to practical limitations in terms of planning and organisation, these activities tend to involve highly constrained solution definition and implementation, rather than showcasing the entire design cycle – in particular the iterative nature of problem definition/user need-finding. While understandable, this focus tends to highlight the convergent part of the design process, with little chance for participants to experience the divergence (and highly creative activities) typical of the early stages of the design cycle [9].

1 DESIGN PROCESS

Design is an integral part of engineering. An applicable and thorough definition of engineering design is given by Dym et al [10];

Engineering design is a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints.

“Design Thinking” is a relatively modern phrase used to describe a process for design that is highly user-centric, drawing upon the disciplines of anthropology and ethnography to enable a designer to create a product which as well as meets specified criteria, focuses primarily on providing the user with a solution to a problem that they may or may not know they have. Although the formalism of design thinking can be largely traced to the early 1990s [11], famous designers/engineers such as Thomas Edison (“Every time you fail you eliminate one way that won't work; therefore being that much closer to the one way that will.”) and Henry Ford (“Failure is simply an opportunity to begin again, this time more intelligently.” & “If I had asked people what they wanted, they would have said faster horses.”) reference many similar themes in their words and deeds. Figure 1 shows the typical process followed in design thinking, the iterative nature of design is represented by the different connections between the steps.

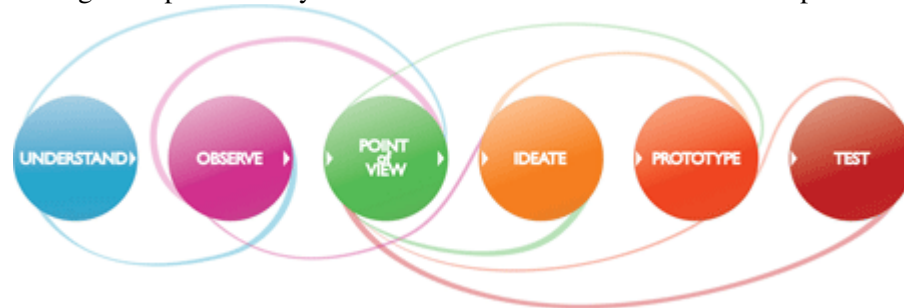


Figure 1 The Design Thinking Process [12]

Design thinking based activities have been utilized as an outreach activity for second level students by several institutions such as the design school in Stanford and the University of Toronto, with research suggesting that these kinds of courses appear to “improve retention, student satisfaction, diversity, and student learning” [10] and also “increase student achievement and attitude toward learning” [13].

1.1 Design as perceived by the general public and potential students

An annual report by the National Science Foundation discusses the findings from a longitudinal survey undertaken by the International Teaching Education Association (ITEA) in 2001 where the associations the public have with the words “technology” and “design” are explored [14]. It was found that the majority of respondents (59%) associated the word design (in relation to technology) with “blueprints and drawings from which you construct something” rather than “a creative process for solving problems.” College graduates were more likely than others to choose the latter definition.

Further studies by the National Science Foundation in a later report show that 42% of people (in the U.S.A.) believe that engineers “design and plan” but that only 4.7% of people believe that engineers are creative [15]. The disparity between these figures suggest that either creativity is largely perceived as being distinct from design, or that engineering design is merely a distinct, minor and non-creative activity within the broader design spectrum.

To investigate what concept of design potential students’ associate with engineering, analyses of print media and CAO course offerings were undertaken.

A search for the word “design” in articles in The Irish Times [16] over a one year period yields a total of 118 articles in the Technology section out of a total of 1,737 articles found. Articles about Facebook, Google, Apple, Microsoft, Audi and BMW account for 76 of the 118 technology articles.

A search for the word “creativity” brought 16 articles related to technology of which only seven articles were on the previously mentioned companies. The figures for the music, film and culture sections were 32, 10 & 93 respectively. A search for the word “imagination” found only nine articles about technology in the past year which is below 2% of the total amount of articles found overall. These results would suggest that the Irish public has a perception of the role of creativity in engineering not dissimilar to the US.

Turning to the CAO offerings; of all the level 7 and level 8 courses available to students in 2012, the largest portion (46%) of courses containing the word design in their description were artistic courses such as graphic design, fine art and furniture design. Only 15% were accredited engineering courses. The other courses (39%) were technical courses such as software design and architectural technology or unaccredited engineering courses [17]. This suggests that either the design element to the engineering courses isn’t being made clear in their descriptions or that there are simply many more artistic courses available than engineering.

The disparity between the recognition of the role of design and creativity in engineering suggests that either creativity is perceived distinctly from design, or that engineering design is but a subset of a greater activity (in design). Furthermore, if the US results are representative, a majority of the public do not even associate design with engineering and those that do overwhelmingly do not perceive it as a creative endeavour.

1.2 Design in the Second Level Curriculum

There are several subjects available that incorporate aspects of design for the Leaving Certificate: Design and Communication Graphics (DCG), Technology, Construction Studies, Engineering, Home Economics and Art.

It is difficult to quantify how much exposure and what style of design methodology the student gets through these subjects. The design process is not explained in any of the curricula apart from that for Technology (see figure 2) and this explanation; “a design-based approach, which is central to the core, requires students to relate their work to the logical steps of a systems approach in the solution of practical problems”.

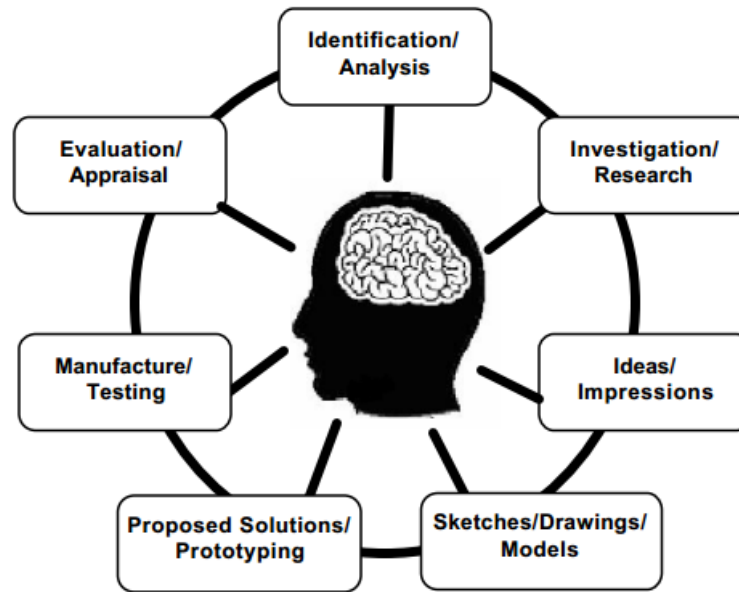


Figure 2 The Design Process as shown in the Technology Curriculum [18]

The Technology Course aims to prepare students “to be creative participants in a technological world” [18]. Design processes are listed as focusses for one of the nine core sections of this subject. Unfortunately it does have a low student take up of only 770 higher level students sitting the exam in 2012 [19].

Design is mentioned in various ways in the other subject’s curricula but detail as to the design philosophy is typically not mentioned. For example, the curriculum for Engineering briefly mentions design, in that the design function includes “selection of materials, shapes, sizes and processes”, but no mention of design thinking methods [20]. Construction Studies appears to be heavily centred on practical learning with an instruction to use “good design practice” in their work without further detail as to appropriate methodologies [21].

2 DESIGN AND FEMALE STUDENTS

It can be difficult for students to realise that creativity and technical skills can overlap and that they do in engineering. This connection may be difficult to make by students due to the separation of school subjects into being either creative or practical with little overlap. Tate director Nicholas Serota believes that this connection isn’t being made and reminds us that “you don’t have to go back to Leonardo to realise that art and engineering are actually pretty close to one another [22]”.

In terms of working with people, Lubinski and Benbow found that “on average, girls and women tend to prefer working with people, whereas boys and men tend to work with things” [23]. Research for the 2008 NAE *Changing the Conversation* study revealed that “young girls preferentially select images of women *doing engineering*, whereas boys select images of *things* that represent engineering” [24]. It is quite possible that secondary school students, and females in particular, do not fully perceive the team work and creativity involved with engineering, two elements that may particularly appeal to female students. Analysis of the uptake of the various design related subjects (as per section 1.2 above) at Leaving Certificate level shows that the ‘T4’ subjects (i.e. those with a design content significantly related to engineering) are overwhelmingly taken by male students – whereas Home Economics and Art are dominated by female students. This is illustrated in Figure 3 below. Even assuming zero correlation between uptake of individual subjects, at most 6% (and possibly as few as 2%) of female students will

have had exposure to this area, while at least 40% will have been exposed to more ‘creative’ design rubrics. For males the pattern is reversed with at least 30% of all school leavers exposed to more convergent modes and at most 20% to divergent modes.

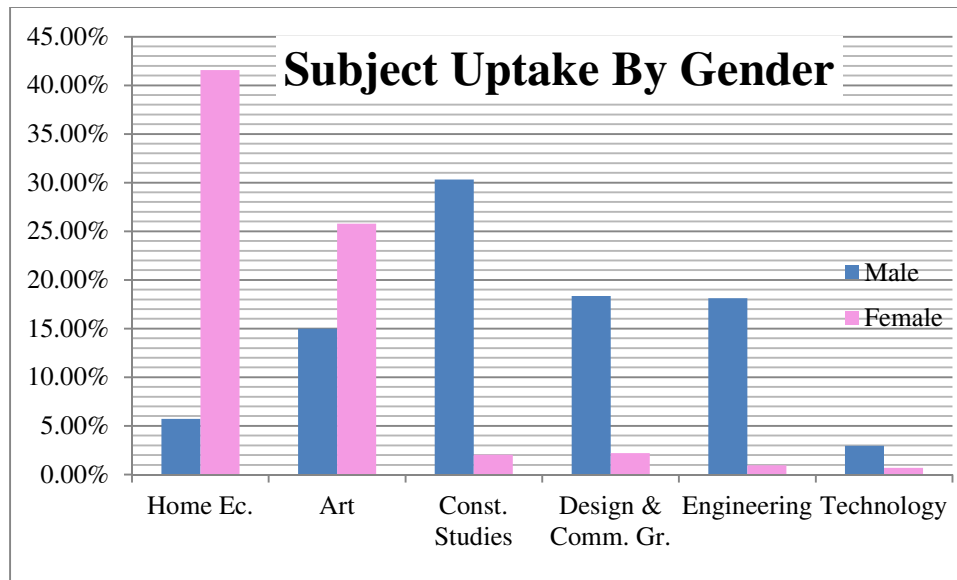


Figure 3 Gender and Subject Uptake for the year 2012 [5]

3 THE DESIGN ACTIVITY

Findings from previous studies suggest that there is a positive benefit to be gained from hands on activities - “This positive benefit of active learning outreach activities was demonstrated both in relation to the lasting understanding of engineering as a profession, and more substantially in relation to the interest among the cohort in studying engineering at third-level” [8]. It was therefore an aim of this work to have the girls participating, drawing, building, testing as much as possible – and to highlight the role of teamwork, communication and divergent thinking in engineering practice.

Following a user-centred design approach, the brief was given to the students as a need that was to be addressed, as opposed to a product that had to be designed. They were told to address the need for a person to organise their keys. This was an open ended brief that they could approach in several different ways. It was also practical for the purposes of manufacture/prototyping that a relatively small product was to be designed by the students.

There were eight girls involved in the summer course and for this activity they were put into two groups of four. It was important that this activity was not explicitly portrayed to be a competition between the teams as creating tension between the girls was a concern. Although competition can be a good motivator, competition against nature rather than peers, can be more inclusive and more beneficial for girls, according to observations made by Sadler [25]. For this reason the focus was to compete against the products already in use instead of each other’s product.

3.1 Activity Context

The mechanical and manufacturing department of Trinity College Dublin have been organising a two week long summer engineering course for secondary school girls since 2008. The objective of the course is to introduce female students who may not have known much about engineering to the reality of engineering as a course and as a career. The activities include demonstrations, experiments, tours, lectures and design. This year was the first year a design thinking challenge was undertaken. Table 1 shows the breakdown of the design activity steps throughout the two week (10 active days) course.

Table 1 Activity Timetable

	Design Step	Approx. Timing
Day 1	• Introduction	15mins
	• Internal and External Benchmarking	75mins
	• Digest Findings	30mins
	• Need Finding	30mins
Day 2	• Divergent Brainstorming	60mins
	• Idea Finalisation and Prototype	105mins
Day 8	• External Evaluation	60mins
Day 9	• Evaluation and Redesign	45mins

The participants built initial prototypes (using paper, card etc.) but not their final prototypes themselves due to limitations with time and materials; they were however informed as to what materials and manufacturing processes could be used for their designs. There were six undergraduate supervisors from the two engineering courses in TCD involved in this course and two of which were assigned to each of the teams to help keep them on track.

4 ACTIVITY RESULTS AND FEEDBACK

4.1 Student Feedback

The students rated the activities (zero to five) in terms of enjoyment in the daily surveys given to them at the end of each day. Follow-up feedback was gathered from a survey which was completed four weeks after the course. Figure 4 shows the scores for the different steps involved in the key ring design activity, with error bars indicating the range over which the girls voted. The combined average score for the activity was 4.17 from the daily surveys and 4.08 from the follow up survey. The many other activities that were run in this course were also marked out of five by the girls. The average mark for these learning activities was 4.19. This leaves the key ring design activity close to average in terms of enjoyment.

Although previously unaware of the steps involved in the design process, they were found to be useful, fun and logical (“the steps in the design process were unexpected but I’m glad we had them”). The scores for each step of the design process didn’t deviate largely from each other, which indicates consistent enjoyment. As shown, the redesign step scored particularly high as well as the brainstorming (divergent) and idea finalisation (convergent). It is noteworthy that both the convergent and divergent ideation steps were considered equally enjoyable in the daily surveys but in the later survey the girls reported the divergent brainstorming as being more enjoyable.

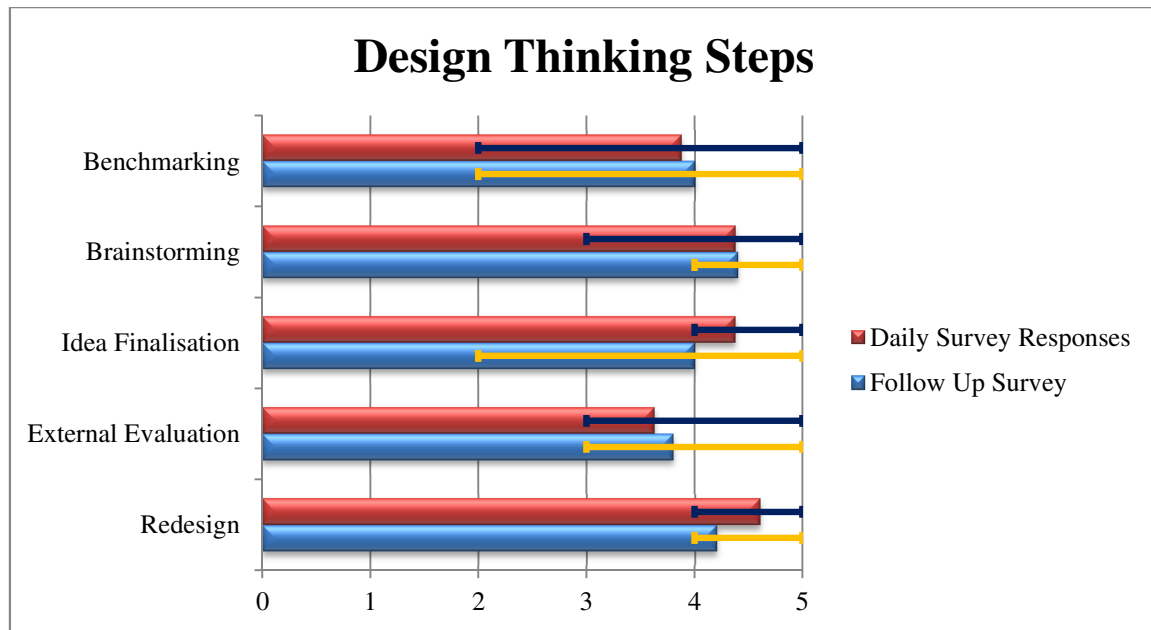


Figure 4 Feedback on Design Thinking Steps

An important aim of this activity was to change the students' opinions of engineering. A follow up survey presented the girls with a list of phrases/words for each of which they were asked to identify if they now (post-course) associated it more, or less, with engineering.

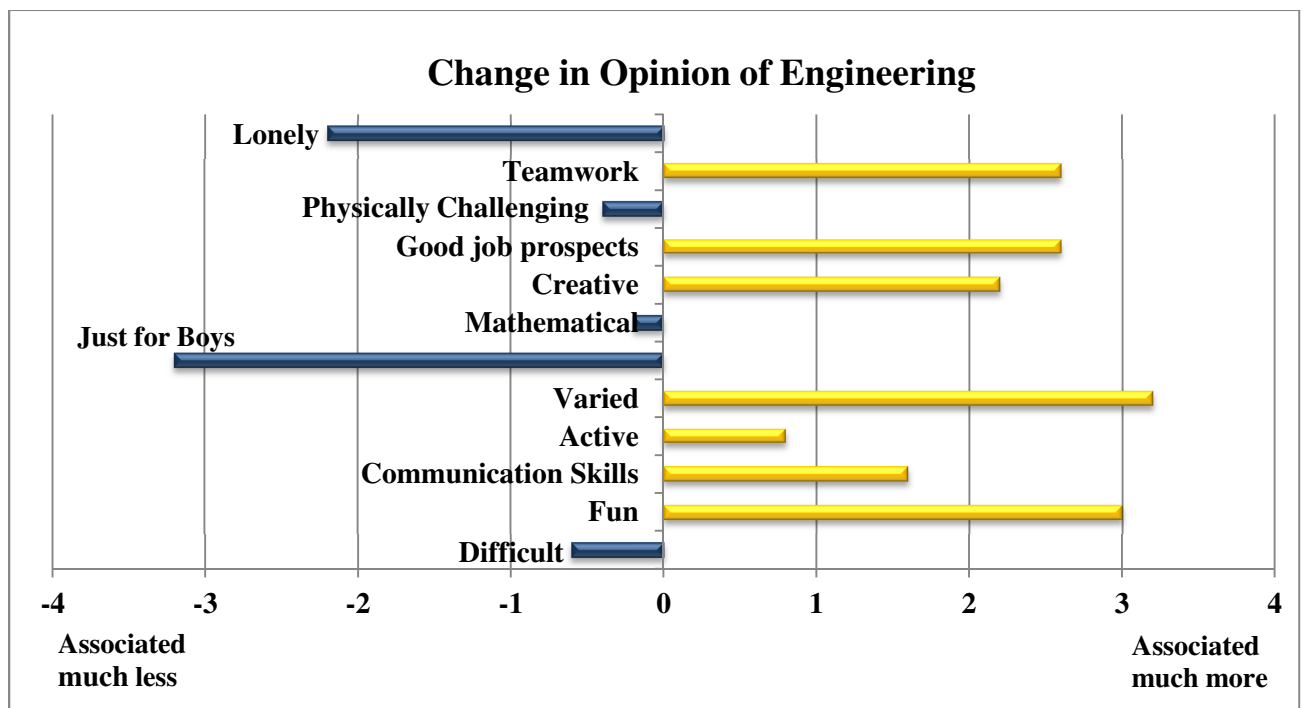


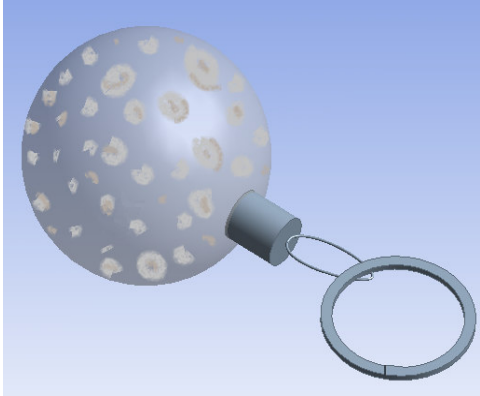
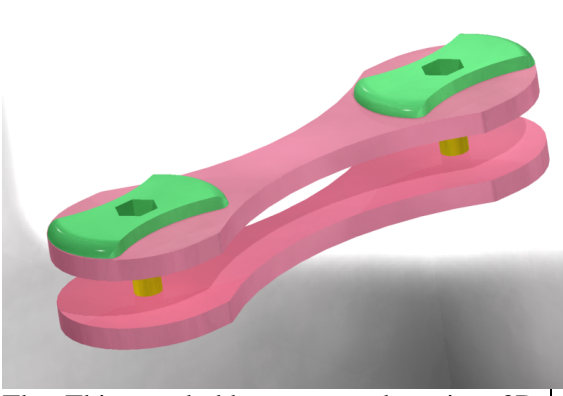
Figure 5 The Increase/Decrease in the Association of Certain Words/Phrases with Engineering

The results show that there was a large increase in the association of the positive phrases with engineering particularly so creativity, teamwork, communication skills and fun. Some of this can be attributed to the key ring design activity in particular, due to the heavy impotence on teamwork and

creativity involved with it. The negative phrases (lonely, physically challenging, mathematical, just for boys and difficult) were all associated less with engineering following this course. In particular the realisation that engineering is not just for boys and isn't a lonely profession seem to be what stuck with them the most. They are realistic in that they still understand that engineering may be somewhat difficult and that it involves maths.

4.2 Results

Table 2 Findings and Process of Student Groups

	Group 1	Group 2
Principal findings	Most people's key rings were given to them as presents and the key rings that one bought for oneself often had a practical purpose.	Many people found the traditional way of getting keys on a key ring annoying, awkward, slow and sometimes painful.
Potential Users	Female, student, mid 20's (collectively decided)	
Key Needs	- Easily find keys in a big dark handbag, - Aesthetically pleasing	- Stores multiple keys, - Aesthetically pleasing, - Easy to use, - Neat
Problem Statement	The user is a <i>female student in her mid 20's</i> who needs <i>to be able to easily find her keys in a big dark handbag</i> because she has a lot of things in her bag and needs to find them quickly.	The user is a <i>female student in her mid 20's</i> who needs to be able <i>to find the correct key on her key ring</i> because she has many different keys and very little time.
Product Name	The Moonkey	Thingymabobby
Prototype	 The Moonkey was designed to look like the moon. However it also had to be semi-transparent to allow the motion sensor internal light to shine through. The material was rubber and it was quite light.	 The Thingymabobby was made using 3D printing. The green attachments screwed to open the device so that keys could be fit onto the inner bars. The prototype could fit eight keys in total, four on each rod.
External Feedback	- Too large, - Strange texture	- Can't fit all types of keys, - The keys swing out freely

	• Didn't realise it was meant to be the moon	• The material is quite brittle
Redesign	• 33% smaller, • More even colour and texture	• Change of dimensions to allow more keys to fit, • Additional flashlight, • Velcro strap to stabilise the keys, • Sturdier material

5 CONCLUSIONS

A multistage design thinking activity, spanning approximately 8 hours of activity over a 2 week period, was investigated as a means of encouraging greater female participation in engineering. Challenges were encountered in keeping groups of students focussed on the task in hand, and mindful of what future stages there would be. These challenges were largely surmounted through embedding of (undergraduate) student helpers into each team. Questionnaires were used to assess student enjoyment and learning on all activities run over the two week program, with follow-up questionnaires (1 month after course completion) also used to assess lasting impact. Enjoyment and learning from the design thinking activities were assessed similarly to other course activities – with marks approximately equal to the overall averages. It should, however, be pointed out, that the other activities are largely well established, tried, tested and optimised – with the design thinking activity being new to both the students and the teaching assistants/helpers.

Support was found for both hypotheses – that the role of design in engineering was under-appreciated, and that design-based activities are particularly suited to attracting more females into engineering. Specifically, word association tests showed significant reversal of previously held stereotypes.

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