What do schoolgirls think of engineering? A critique of conversations from a participatory research approach

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Abstract

Whilst statistics vary, putting the percentage of women engineers at between 6%[1] and 9% [2] of the UK Engineering workforce, what cannot be disputed is that there is a need to attract more young women into the profession. Building on previous work which examined why engineering continues to fail to attract high numbers of young women[3,4] and starting with the research question "*What do High School girls think of engineering as a future career and study choice?",* this paper critiques research conducted utilising a participatory approach[5] in which twenty semi-structured in depth interviews were conducted by two teenage researchers with High School girls from two different schools in the West Midlands area of the UK. In looking at the issues through the eyes of 16 and 17 year old girls, the study provides a unique insight into why girls are not attracted to engineering.

Introduction: Background

Like most years, 2013 saw its fair share of global disasters and advances which varied in nature from a nightclub fire in Brazil in January which killed 250 people[6], to an aircraft accident at San Francisco airport in July[7], through to Typhoon Haiyan which devastated the Philippines in November 2013[8]. Whilst on the positive side, advances in 3D printing[9], a new British research centre in Antarctica[10] and a probe sent to Mars by the Indian Government[11] represent some of humanity's most recent and exciting advances. In looking at such disasters and triumphs one commonality immediately jumps out – they are concerned with some aspect of **engineering**. It is this centrality to human existence that makes engineering so important to our everyday lives; yet despite this importance, the profession in the UK is currently facing dire shortages[12, 13].

Defined by the Encyclopaedia Britannia[14] as "*the application of science to the optimum conversion of the resources of nature to the uses of humankind*", engineering is generally perceived as a bridge between science and society across which engineers apply scientific principles for the betterment of humanity[15]. Yet despite the discipline's continued centrality to the advancement and development of society, and the central role played by engineers as society's problem-solvers and critical thinkers[16,17,18] , Engineering Faculties in the UK and the EU continue to experience difficulties attracting suitably qualified candidates onto undergraduate programmes. Moreover, having struggled to recruit students, many Engineering Programmes find themselves beset by high levels of student attrition – the culmination of which inevitably results in shortages of young people entering the profession at graduate level[15,19,20,21,22]. Given such shortages it is perhaps surprising to note that across much of the developed world the Engineering Profession itself is beset by gender inequities in terms of the number of women engineers. National statistics, whilst not providing an 'exact' comparison, do provide insight into the numbers of women within Engineering. For example, within the UK the literature suggests that only 9% of Engineering Professionals are women, compared with 18% in Spain, 26% in Sweden and 20% in Italy[2]. The low figure in the UK reflects that of the USA where previous studies indicate that only 11% of Engineers are women[23] and in Australia where 14% of Engineers are women[24].

Explanations in the literature as to why so few women select to become engineers, or 'natural' scientists, have long been the subject of debate[25,26,27,28] with some research

identifying stereotypical images of engineering as being more suitable for men as being a primary cause of women's reluctance to enter the profession[29,30]. Other literature suggests gender-specific interventions may be putting women off becoming engineers. Such barriers include: Inequitable career progression for female and male engineers reflective of difficulties women may experience balancing work and family[23] and meaning that women find it more difficult to get promoted: Gender-specific role socialisation resulting in women engineers having low self-confidence levels[31] : Too few accessible or high profile female role-models[32] : Differences in power-relationships and values within the engineering profession itself, resulting in men being placed in the more powerful positions and once there, exercising a patriarchal bias in all areas at all levels[33].

Methodology

In seeking to investigate how teenage girls view engineering as a potential university level study subject and career option, a participatory research approach was adopted[5] in which two 17 year old female High School students were employed as interviewers. The girls, who were employed during their summer vacation, were given basic research methods training including how to conduct a semi-structured interview. They were also given some training in the 'practicalities' of qualitative research (including the organisational aspects, such as arranging appointments, recording interviews and transcribing verbatim discussion). Following a brief literature review, the research process commenced with the development of the research tools. During this stage an interactive 'thought-shower' session was arranged during which the girls and the two researchers worked in partnership to consider in some detail, the issues around engineering and engineering education from the girls' individual ontological and epistemological perspectives. Following this session the two girls worked together to develop a qualitative interview guide, this was then refined with the researchers before being used throughout the interviews.

A total of twenty young women aged 16 and 17 years were interviewed all of whom were British. Four of the girls were from Black or Minority Ethnic backgrounds (BME), the rest were from White Ethnic groups. Fourteen of the interviews were conducted during the summer of 2012, with the remaining six being undertaken during the Easter break, 2013. The sample originated from two very different schools with half of the participants coming from one of the UK's leading State Girls Grammar Schools (School 1); this school has an exceptionally demanding entrance examination and only accepts very high achieving pupils. The remaining interviewees were from an inner-city, mixed-gender, Church of England School (School 2). This second school, which is also in the state sector, takes children of mixed abilities. Both schools are classified as 'outstanding' by the UK School Inspectorate. Both are located within the same city about 4 miles apart. It should be noted that two high achieving schools were purposefully selected for the study in order to allow for a reasonable comparison. Both schools attract young people from a range of ethnic groups, religions and social classes.

The interviews took place over a three week period. Each lasted between 30-45 minutes. The interviews were recorded and transcribed. The data was analysed by the two researchers using qualitative techniques. The qualitative nature of this study means that the findings are not generalizable. However, although the sample size is quite small, the depth of data acquired suggests that the girls' perceptions may reflect those of the wider sampling frame (although further research needs to be conducted to determine whether this is the case).

Findings

By employing two teenage girls to talk to other teenage girls about engineering, the participatory approach afforded a depth of insight and data that has not previously been available. Getting girls to talk to girls about how they viewed engineering and the prerequisite subjects required to study the subject at university meant that the researchers were able to 'draw' out a living perspective, looking through the eyes of the target sample group. This 'first-hand' approach proved a success with many different issues raised and discussed. A number of these are discussed below.

In focusing on the influences impacting girls' perceptions of engineering and applied science the analysis identified two major underpinning factors: Educational; and Socio-Professional. Each one of these is now discussed in turn.

- **Educational Factors**

In planning how the interviews should be conducted the two teenage researchers reflected upon their personal experiences of making the transition from Primary to Secondary Education. In particular, it was apparent that the way in which the girls were taught maths and science at Primary School differed significantly to the learning and teaching approaches they were later exposed to during High School. In keeping with the participatory approach, the interviews started off by exploring this issue in some depth.

The first questions encouraged the girls to reflect upon how, and when, science and maths were first taught at infant and junior level (K-6). For many of the girls, their first recollection of science was at around the age of 6 or 7 years whereupon they were introduced to biology and botany:

> *[In Primary School] … we had lessons on science…. from what I can remember the focus was really on biology, like animals and things. We didn't really do much chemistry or think about the way things worked.*
>
> Jodie. 16 years. School 1.

> *We just looked at plants that we had in a garden and how many there were in certain areas … … it was just random really.*
>
> Mel. 17 years. School 2.

> *I remember in Year 2, we used to look at the body and how it works and how things move… …*
>
> Roshni. 16 years. School 2

Whilst for some of the girls' science was perceived as being almost exploratory in nature, when asked about their memories of learning maths at primary level almost all described a pedagogy based upon 'rote' learning:

> *In Primary School you just listened to what the teacher did and you did the same.*
>
> Sahar. 17 years. School 1.

In maths, at Primary School we used to only do adding, subtracting, multiplying and dividing.

Sonya, 16 years. School 1

It was very specific and I suppose in primary school you just sort of learnt it and it was like 'look it happens'

Mo. 17 years. School 2.

Although maths was taught universally to all of the girls from the age of 5 years, their exposure to science differed. In reflecting upon the differences of how science was taught at primary level compared to secondary level, most of the girls recalled that once in High School, Science became increasingly more difficult as it was extended to include chemistry and physics:

Well, [at Secondary School] Science obviously split into chemistry, biology and physics - which was a whole new concept because I had no idea…

Tessa. 16 years. School 1

Science got harder and stricter in Secondary School… It became less interactive you had to do more listening than just doing practical stuff.

Ellen. 16 years. School 2.

Science, in Primary School it was very basic… we didn't know the difference between biology, chemistry and physics. At Secondary School we do experiments

Sonya. 16 years. School 1.

Like science, maths was noted by the majority of the interviewees as being much harder at Secondary School. This was particularly the case for the pupils from School 1:

Maths [ ] got harder, I think I found it much easier in Primary School where I was better at it. I went down in High School, I wasn't as good …. It got more complicated and there were some things that I didn't really understand.

Jen. 16 years. School 1.

Maths, it was the same layout as before, but it got harder and you learnt more about the specification…

Sonya. 16 years. School 1.

Almost exclusively the shift between Primary and Secondary School, maths and science was perceived negatively by the sample irrespective of whether they were in School 1 or 2. This suggests that the subjects are not smoothly aligned across the different levels of the curriculum – making the transition from one level of education to the other somewhat difficult.

Once at Secondary School all of the girls were introduced to the concept of science comprising three different disciplines - physics, biology and chemistry. For the majority,

having been exposed to the three different subjects, biology and chemistry were identified as being preferable to physics. From the girls' perspectives the reasons for this varied greatly:

> *Biology is very relevant to everything. I find it interesting because you come across things in science all the time but you don't always think about how they happen. I enjoy physics the least, I don't know why as I always did best in physics but I just didn't find it as interesting. It was the least useful f or the career I wanted to go into and I never really found it as enjoyable.*
>
> Sonya. 16 years. School 1.

> *I prefer biology. Definitely. It's there, you can see it. With physics, you can't see the forces, with chemistry you can see the experiment but I don't find it as interesting. But with biology, you can see how it works on your own body and stuff.*
>
> Jodie. 16 years. School 1.

> *Between biology and chemistry, I enjoyed the practical side of chemistry but I enjoyed learning about the body in biology, so more biology probably, dissecting and cutting things up. I didn't really enjoy physics though. It wasn't as interesting, it just wasn't. You learn physics but it's not practical based as much and it's not as interesting… Its things you can't see whereas I prefer things you can see….*
>
> Mel. 17 years. School 2.

> *I liked blowing things up in chemistry but I also enjoyed dissecting an ox's heart in biology because you got to see things like what they are what they're really like, and it's totally different to a diagram. Physics was my worst subject. I don't know why but physics always used to scare us about nuclear bombs and thing like that, what the outcome would be if there was one which was all a bit scary…*
>
> Sahar. 17 years. School 2.

> *I like physics the least. It is the hardest and some of the things seem quite obscure to me. They were things that I didn't want to do, that I wasn't interested in. It was the calculations and equations, there are a lot of them to memorise, which is not as interesting as getting involved with the subject. With an equation, you write it down and memorise it whereas with biology, it's with the body and you can get a bit more involved with it. You can bet into it a bit more.*
>
> Emily. 16 years. School 1.

Of the 20 interviewees, only three preferred physics to the other sciences:

> *I chose physics because I am good at it and I really enjoy it. Maths the same. Chemistry because I might need it for the university course I want to do and classics because I really enjoy the lessons. But I enjoy physics the most. I find it really interesting, especially the space topic. And I find it the easiest as well.*
>
> Belle. 16 years. School 1.

I think I became more open minded with physics as I got older. Before that, I didn't like the teachers and that made me take it out on the subject - so I didn't even bother trying. Then at GCSE I knew I had to do well, which made me concentrate and then I realised that I love physics.

Kelly. 16 years. School 1.

I enjoyed physics the most mainly because of the teacher that I had but also because it was learning about the outside world and what effects it has on it.

Mo. 16 years. School 2.

The girls' preference towards biology reflected their wider work and career interests. Furthermore, the interviews revealed that it is not physics itself that the girls disliked (although there were some aspects which they found 'scary' such as the lessons on nuclear war), instead they appeared to have been put off by the way in which the subject was taught. Most of the interviewees perceived physics to be an abstract subject, of little or no relevance to their lives – indeed, all but one were unable to relate how it fitted into their current lives or future careers.

- **Socio-Professional Factors**

Within the UK Secondary School education system the curriculum for those age 11-14 years is consistent across most of the country, with all students being introduced to the key subject areas associated with the disciplines of: English: maths, science, humanities, design & technology, modern languages, and arts at the age of 11 years. The first three of these are compulsory subjects, which have to be studied until a child reaches 16 years[1] whilst the subjects encapsulated within the humanities, design & technology, modern languages and arts disciplines form the basis of 'GCSE[2] Options' whereby children have to select up to 8 additional subjects to study until they are 16 years of age.

Having taken their GCSE examinations all of the girls then selected to continue with their education at each of their respective Schools. This entailed selecting 3 subjects for study at GCE Advanced level ('A' level)[3]. Choices made at 'A' level are of vital importance as they impact the student's choices with regards to future careers and / or university level study. For the majority of the sample, parents played a significant role in guiding and influencing what subjects were taken at 'A' level; notably, this was particularly the case for girls from School 1:

Yeah, my mum said I had to take 'real' subjects, whereas I wanted to take other subjects. If I had my choice, I would be doing psychology at A-level, but mum said no.

Jodie. 16. School 1

It was probably my parents or were the greatest influence on what

[1] Science may be taken as a 'Combined subject' (a qualification that is perceived to be of lower academic value) or as three individual subjects (Physics, Biology, Chemistry). All children must study at least one Science subject until they reach 16 years.
[2] GCSE: General Certificate of Secondary Education: The examination mostly taken at 16 years (High School Certificate level). Subjects are grade A* - G with grades A* - C being accepted as an appropriate level for GCE (General Certificate of Education)
[3] GCE 'A' Level. General Certificate of Education: Advanced level study. Universities generally require 2-4 'A' level passes and 5 GCSE grades A*- C (although the grades for admission vary greatly across institutions)

I did for A level. We sat down and talked about what I liked, what I wanted to do, which ones they thought I should do, which universities would be good, that sort of thing.

Helen. 16. School 1

I had a lot of trouble choosing my A-level choices, choosing between physics and biology. My parents helped a lot with that, encouraging me to do the one that I enjoyed the most.

Belle. 16. School 1

However, for a minority of the girls parental influence was not a factor in determining their subject choice:

My parents didn't influence me so much my A-Levels, I pretty much set on what I wanted to do but for GCSE not all of them but maybe one, I had my heart set on a subject but my parents sort of nudged me away from that, I find it now that it was a good thing that happened but mainly it was my choices.

Mo. 17. School 2.

My parents didn't really say they'd have liked me to do a science anyway, [ ] they didn't put any pressure on me.

Sonya. 16. School 1.

In addition to parents, other less prominent influences on the girl's subject choice included their peer group and the media:

The media was an influence I suppose whenever there was information about universities and what jobs there were a lot of vacancies in… I suppose I paid attention to that, I wanted something that might have a bit more of an instant reward as bad as that sounds.

Tessa: 16 yrs.: School 1

Probably my friends were the biggest influence on what I chose, because I have a lot of friends in university in Birmingham and London and a lot of them are studying optometry and doing research into bio-chemistry and stuff, so they seem to be enjoying it and they give me an insight into it.

Kelly. 16 yrs. School 1

It should be noted that engineering is not a subject widely offered to British School children at either age 14 or 16 years. The lack of priority given to engineering as a subject for pre-university study is reflected in the number of teacher training places offering engineering as a specialism. Indeed, out of 1,256 Teacher Training programmes offered in England only 4 offer Engineering[34]. For many children, and their parents, the fact that engineering is not on the curriculum undoubtedly plays an important part in shaping the girls' views of it as a future study and career choice. Whilst all of the girls had given a considerable amount of thought as to where they wanted their career to go only one had seriously considered engineering as a viable option and for this student, the main influence in her choice was her own father:

I did think about engineering, when it came to A-Level choices I was very tempted to take some sciences and maths because I felt that I should follow my Dad's footsteps and go into engineering and obviously I went into Dad's office all the time so I knew quite a lot about it. I used to see all the funky posters on the wall so I did consider it but as I went through GCSEs I found where my strengths lie, where the things that I enjoy lie and I guess I realised that it just wasn't for me"

Tessa. 16 years. School 1

Whilst parental, peer and media influences played a part in shaping the girls choices of subjects to study at 'A' level when questioned about whether they would consider engineering as a career the majority identified gender based stereotypes as being a major factor:

There are some female prejudices against sciences, against engineering especially. I think people don't think it is as important as stuff like medicine and so they don't even bother thinking about physics.

Kelly. 16 years. School 2

I think peoples' perceptions are that engineering is not really for girls, but when it comes to it anybody can do it really.

Chrissie. 16. School 1

I would say engineering is mainly for men…

Melanie. 16. School 1

Although the majority of the girls perceived engineering to be a male dominated career, for some such views were based on their own experiences of being in contact with engineering and engineers via a parent or other family member:

It's definitely very masculine based. When I used to go to work with my Dad the only women I remember were the receptionists, so yes very masculine, very male dominated. But that never deterred me because my Dad was always open to me. I didn't really notice the gender.

Tessa. 16. School 1

I only know males that are engineers. I don' know any women despite my Dad being an engineer. But I do think that being a girl doesn't matter if you want to become an engineer. I just don't know anyone girls that do.

Sahar. 17. School 2

My Dad and Brother are engineers. I know there are a few women who are, but compared to the amount of men it's only a small figure. But, although women can become engineers, I just don't think females find it an appealing subject, job, or career.

Ellen. 17. School 1.

In looking at the data as a whole there were a few notable differences between the perceptions and experiences of the girls' from each school. Such differences centred on perceptions of maths and science at secondary level; however, perceptions of engineering in terms of it not being a suitable study or career choice were relatively similar.

Discussion

In considering the pedagogical factors influencing teenage girls, this study reinforced the findings of previous work that children's transition into High School is a major issue in need of attention – particularly in relation to the teaching of maths and science. Throughout the interviews primary level education was described as being experiential in nature, whereas secondary level education, particularly in relation to physics and maths was noted to be far more conceptually and theoretically grounded. Whilst all of the girls only recalled receiving a limited amount of science education during their Primary School years, the majority asserted that having made the transition to High School the *difference* in how science and maths were taught was so great that they often struggled with the subjects, quickly losing interest as a consequence[35,36,37]. Given the nature of the two schools in the study, in that both are identified as "high achieving", this trend is clearly concerning. In considering the study findings it is not unreasonable to suggest that experiential learning should not diminish when a child reaches the age of 11 and enters Secondary Education. For children's enthusiasm and interest to be maintained and developed, education needs to be both relevant and realistic - with key scientific and mathematical principles embedded within a wider social context. Furthermore, if more young people are to be encouraged to consider engineering as a career then more needs to be done to maintain and develop children's interest beyond the age of 12 or 13 years. The ways in which this could be achieved undoubtedly merit further investigation; however, one area which deserves immediate attention is the need to expand Primary and Secondary Education so that it encapsulates engineering both as a distinctive subject but also as a foundational subject potentially underpinning much of the wider curriculum. Indeed, it is not unreasonable to postulate that the nature of engineering means that it could potentially provide the ideal context in which science, maths and other disciplines (including history, English and ICT) could be embedded into the curriculum in a practical and meaningful way[3].

With regards to the factors impacting teenage girls' views of engineering as a discipline within itself, and also as a potential study and career choice, the most notable factor shaping their perceptions was a lack of knowledge, exposure and experience. In the UK, as elsewhere, engineering does not feature on either the Primary or High School curriculum – hence it is simply not something girls think about! Whilst science and maths are compulsory from the age of 5 to 16 years, over half of the girls 'dropped' maths as soon as they could. Furthermore, only one had selected to study physics beyond the age of 16 (she wanted to become a scientist, not an engineer). Of the rest, over half were studying at least biology or chemistry at 'Advanced' level – with their future career choices being focused upon a range of potential professions including physiotherapy, psychology, optometry and medical practitioner[4].

[4] All of the interviewees have now graduated from high School. All of the girls from School 1 have gone onto university, studying a range of subjects including Physics, medicine and medical related subjects, classics and history. 6 of the 10 girls from School 2 are now at university and are studying an equally diverse range of subjects including business and psychology.

Interestingly, most of the girls included in the study were able to articulate what they believed 'engineering' is; however, on the whole their perceptions were inaccurate with almost all perceiving it to be a male-dominated discipline. This perception is possibly reflective of the industrial nature of the city in which the two schools are located, where historically their fathers and grandfathers would have often entered the engineering 'trade' (at an apprenticeship level) to work in one of the major industries of the mid-20th Century. A decline in industrialisation resulted in mass redundancies in the late 20th and early 21st Centuries. This has undoubtedly negatively impacted popular views about engineering, with many working class people perceiving it to be a dirty occupation in which there is no future[38,39].

In considering the girls' perceptions of engineering, an important factor is reflected in how much exposure is given to the discipline whilst at school. What this study has clearly shown is that there is a dire need to raise children's awareness of what engineering is in terms of the discipline itself and also in terms of the potential career options it could lead to. Whilst all of the girls interviewed believed women could be engineers, none wanted to study the subject at university. Notably, the possibility of engineering apprenticeships was not even mentioned despite the working class demographic of much of the sample. In considering the wider context in terms of future career aspirations, it should be noted that whilst around half of the girls wanted to follow careers in science, medicine or health the majority of the interviewees had achieved reasonable grades in GCSE maths and science at the age of 16 (with those from School 1 achieving much higher than the national average). Thus, in looking at potential of the sample to become engineers, it is evident that had they been encouraged to consider engineering as a career from an early age, most could have entered the discipline had they wished to do so (either as apprentices or via university level study). Indeed, all of the girls studied the pre-requisite subjects of maths and science (including physics) until the age of 16, with the majority going onto study maths and at least one other science at 'A' level. The fact is that with one or two notable exceptions (where individual girls had family members who were engineers), engineering was simply outside of the girls mindsets and as such was not considered as a potential career. This raises the question: *What can be done to raise the profile of engineering in such a way so as to encourage more capable young women to seriously consider it as a viable and exciting career*?

Whilst this study has shown is that there are no simple solutions to this question, one thing that did become apparent during the study was the lack of positive engineering role-models (both female and male) that children, young people and even teachers have access to. Most of the sample, like the majority of children, had simply never met an engineer! This is one issue that the professional bodies can do something about – by encouraging young engineers, both female and male, to go into schools to work with teachers and children. The introduction of such role models needs to be firmly grounded in the need for a sustainable culture change within the UK education system and wider society as a whole. Such change needs to recognise and celebrate engineering as an option for girls (as well as boys). Moreover, whilst the manner in which maths and science are taught in Primary and Secondary Schools is something the UK Government urgently needs to look at. Furthermore, individual engineers also have a vital role to play by going into schools and actively engaging with young people, providing a living example of what is an exciting, satisfying and worthwhile career (irrespective of an individual's gender, social class or other demographic characteristics).

Conclusion

Whilst there is a need for the engineering profession to assure its sustainability by attracting both young men and women, that young women do not appear to perceive engineering to be a viable career option represents a serious challenge for both engineering education and for the wider engineering profession. Indeed, it is clear that if society is going to begin to address future predicted shortages of engineers, the need to attract young women into engineering is of paramount importance and urgency. The emergent findings from this study suggest that one of the first steps that need to be taken to address the issues is to look closely at the National Primary and High School Curriculum. For girls (and indeed boys) to consider engineering as a potential and viable career option the subject first needs to become embedded within their everyday language and learning. Moreover, there is a dire need for the profession to address continuing stereotypes that engineering is a male dominated occupation with no room for ambitious young women.

In conclusion, each of the issues identified in this paper cannot be addressed in isolation. Likewise none of the matters discussed are the sole responsibility of government, professional bodies or education providers; only by working together to engage children with engineering and its associated disciplines from an early age will the barriers to engineering discussed in this paper begin to be addressed and future predicted shortages of engineers averted.

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