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A Community Based Participatory Research Study into Why Some Girls Don't 'Do' Engineering*

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One of the main issues faced by British Society today is reflective of the fact that there is a documented shortage of young people selecting a career in engineering. This is particularly the case when it comes to young women, many of whom simply don't consider engineering to be suitable for women. The reasons for this are well documented but are undoubtedly worsened by the fact that only 6% of UK Engineers are female. Taking into account previous studies focusing on the issues of gender in engineering, a community based participatory research approach was adopted in which the reasons why teenage girls fail to view engineering as a viable future study or career option were explored. Two 17 year old female high school students were trained as participatory researchers and employed to conduct semi-structured interviews with their peers. A thematic analysis of the data was undertaken whereupon two distinctive themes emerged in relation to how girls' perceive engineering. The first theme reflected girls' lack of knowledge about what engineering is, whilst the second was related to their views of engineering as a potential career. Verbatim quotes are used throughout the paper to give the teenage participants a previously unheard 'voice' in the debate about gender and engineering. The paper concludes by arguing that although engineering has much to offer young women in terms of a potential future career, the main issue is that they lack awareness of what engineering is and what engineers do.

Keywords: gender issues; engineering; participatory research; teenage girls

1. Introduction

Despite numerous high profile campaigns to attract women into engineering, recent figures suggest that only 6% of UK engineers are female. At the heart of these figure are arguments that girls and young women are not attracted to engineering as they perceive it to be dominated by white, middle class, middle-aged males. Taking into account previous studies which looked at the issues around gender and engineering, this study set out further explore the reasons why young women fail to consider engineering as a viable future study or career option. In seeking to investigate the underpinning issues, the paper draws upon the findings of a small participative study in which two 17 year old female high school students were employed to interview their peers about engineering. By employing 'girls to talk to girls' about engineering, the paper authors gained a unique insight into the issues through the 'eyes of teenage girls'. In analysing the data, two distinctive themes emerged as relevant to girls' perceptions of engineering. The first of these relates to matters of definition whilst the second focuses upon the girls' views of engineering as a 'career choice'. Using verbatim quotes, the paper gives the teenage participants a previously unheard 'voice' in the debate about gender and engineering. It concludes by arguing that although engineering has much to offer young women in terms of a potential future career, the main issue is that they lack awareness of what engineering is and what engineers do.

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2. Literature review

2.1 Background: Shortages of engineers: The butterfly effect

Looking across the European Union, the culmination of a six year recession [1] and a widely reported 'skills shortage' [2, 3] has left a number of leading politicians with something of an unprecedented predicament articulated by the question "*How can Europe compete globally, when insufficient numbers of young people are selecting a career in engineering to meet the future needs of our society*?" Grounded in the premise that engineering is ". . . vital for a successful and sustainable civilisation" [4] questions of how to attract more young people into engineering continue to plague educators, professional engineers and policy makers alike. Yet, despite having entered a new epoch in terms of the current 'Digital Revolution' [5], the United Kingdom in particular is faced facing unprecedented shortages of engineers with only 12000 graduates in 2013—enough to fill around 20% of the vacancies [6, 7]. Arguing that during the decade, 2012–2022, the UK Engineering Sector will need to recruit 2.56 million people,

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equating to 17.8% of all vacancies across all industries, a report by Engineering UK (Pg 10) notes that this is ". . . *equivalent to 47.2% of the current engineering workforce (5.4 million)*". Furthermore . . . "*Of these workers, 1.82 million will need engineering skills: pro rata, that is an average of 182,000 people per year. Occupations at level 4+ (HND/C, foundation degree, undergraduate or postgraduate and equivalent) are most likely to require engineering skills, and these account for approximately 107,000 openings per year*" [8]. In considering this and other evidence a number of important questions are raised, the first of which relates to the global implications of the shortages of engineering talent.

A report by UNESCO (2010) suggests that an acute shortage of engineers will negatively impact global development in the short-term, whilst in the longer term such a shortage could significantly hinder environmental, social and economic sustainability. From a UK perspective, any possibility that shortages of engineers may indeed be a global problem, can only be viewed as bad news—as the UK increasingly turns to overseas recruitment to fill future engineering and applied science vacancies [4]. Politically, a number of high profile industrial leaders and politicians are united in their concerns that current and future shortages of young people choosing to enter an engineering career can, and will, damage the UK's economic and scientific prospects [7, 10, 11]. Within this uncertain climate, and despite the fact that over the past 10 years much effort has been made to attract young people to study the applied sciences at school level [12–14], Engineering Schools across Europe find themselves continually struggling to attract suitable candidates onto Bachelor's level programs. Furthermore, having started university, engineering students are quite likely to drop out, an issue that represents an ongoing and somewhat unfathomable problem for those tasked with maintaining student numbers [15, 16]. Looking at this from a Gestaltist perspective, it is not unreasonable to argue that the 'butterfly effect' of current shortages of engineering students may well result in long term and perhaps irretrievable social and economic damage, both in Europe and much wider [17–20]. The question then becomes "What can university educators and policy makers do to prevent future shortages of engineers?'

2.2 Radical or Reasonable? Time to address the gender gap?

Having established that in order to address current and future national and international shortages of engineers, something needs to be done, and quickly, the uncomfortable question of gender inequalities raises its head. Whilst many engineering faculties across the globe continue to struggle to attract suitable young people of either gender onto their programs, the fact remains that internationally, engineering is not viewed by the majority of young women as a potential suitable career option. The UK in particularly stands out as a country where women don't do engineering, as only 6% of engineering professionals in the country are women [21]. In Spain, the situation is slightly better with 18% of all engineers being women, whereas in Sweden and Italy the figure is 20% [22]. The low number of women engineers in the UK is reflective of other English speaking countries, for example in the USA women make up only 11% of the engineering workforce [23] whilst in Australia the figure is just under 12% [24].

A depth of literature exists in which a number of explanations as to why so few women select to enter careers within the engineering field are posited and debated [25–27]. Whilst such debates draw attention to gender stereotyping and public perceptions of engineering as ostensibly being a *"man's job"*, historically this has not always necessarily been the case. In the Second World War thousands of women took up engineering roles, working in what were previously 'male only occupations'. The varied in nature from jobs in construction and civil engineering, to building aircraft and ships for the war effort and working in the munitions industry [28, 29]. Yet, even at a time of national emergency, women working in engineering-related occupations found themselves subject to discrimination. The Trade Unions Movement offered little succour, expressing concerns that if women were employed in jobs that were generally perceived to be within the 'male preserve', the *value* of those jobs would decrease, resulting in lower wages being paid to men once they returned from the war. Whilst some agreement was reached regarding '*equal pay for equal, unsupervised work*' many British employers circumvented this, arguing that women couldn't work unsupervised. Throughout the war this resulted in female engineers being paid only 53% of the wage paid to men in similar occupations [30]. Likewise, in the USA, a severe shortage of engineering talent during the second world war led Engineering Faculties to purposefully recruit young women [31] with the specific aim of making sure that the war effort was fully supported. Yet, once again, as soon as the war was over, engineering returned to becoming mainly the preserve of men, with women being directed back into the home or guided into more traditional roles such as nursing [32]. Whilst over 70 years have gone by, it appears little has changed with regards engineering being perceived throughout the Western World as being a 'male occupation'. Women are still directed towards more 'feminine

careers' and engineering remains ostensibly a male-dominated.

The reasons why engineering continues to be viewed as a male occupation across much of the world is the subject of much debate. In looking across the literature, and taking account of contemporary culture, it may be surmised that one of the main reasons there are so few women in engineering in Western Society reflects stereotypical images of engineering commonly promoted in the media and elsewhere. Such stereotypes suggest the engineering is dominated by white, middle class men—an image that may simply act to 'turn off' young women [33, 34]. Other research points to a number of gender-related barriers which act to negatively influence young women's perceptions of engineering. Such barriers include; concerns about the impact that having family responsibilities may have on promotion and career opportunities [23]; a lack of confidence in terms gender-role socialisation and how male colleagues may view women in the workplace [35]; a scarcity of successful women engineers to act as role-models [36] ; and the belief that male managers and executives are reluctant to appoint women to engineering roles [37]. The culminative effect of these barriers appears to be that women may believe there is little point in applying for an engineering position.

Looking at the situation as a whole, the difficulties in attracting young people of both genders to engineering can only be augmented by the gender-related barriers faced by half of the potential talent pool! There is clearly a need for radical action to be taken to address the gender gap in engineering. However, before Engineering Educators consider what strategies and action need to be put in place to address the gender gap, there is a need to further investigate the underlying issues which reinforce and sustain the gender gap. In seeking to do this, a small study, entitled the "Girls into Engineering Study" was undertaken. The study used participatory research methodologies to directly sample a small group of teenage girls. In doing so it investigated their perceptions and views of engineering, both as a concept and as a potential career, is some depth.

3. The "Girls into Engineering Study": Methodology

3.1 Research Design

Utilising an approach based upon the principles of Community-Based Participatory Research (CBPR.), two 17 year old High School girls were employed as Participatory Researchers. Valuing the role of members of the community and researchers equally, CBPR is a particularly useful philosophical approach to social research when access to a particular community is found to be difficult [38]. Starting with the Literature Review, Fig. 1, provides a diagrammatic representation of the methodology adopted during the course of the Study.

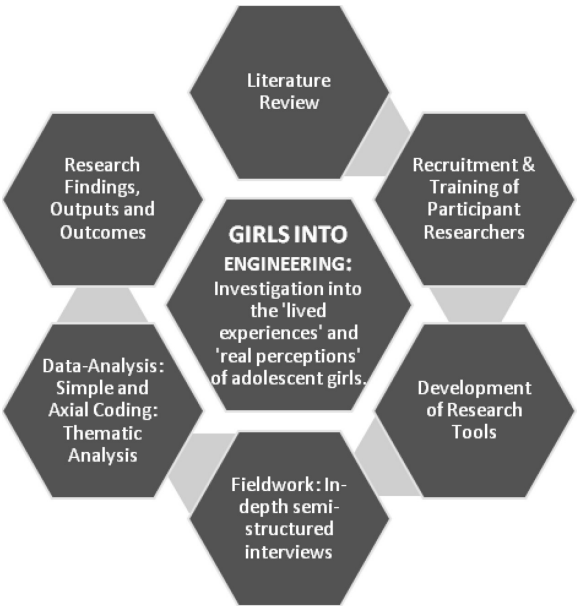

Fig. 1. The Girls into Engineering Study Methodology: Conceptual Framework.

The approach depicted in Fig. 1 proved to be particularly suitable for the 'Girls into Engineering Study' as, by employing girls two teenage girls to interview their peers, the two academic researchers were able to gain first-hand insight into the lived experiences and perceptions of a small group of British teenagers at the end of their 'compulsory education'. Unlike more 'traditional' approaches, by adopting an approach based upon CBPR, the study methodology followed a 'participant-centered' approach right from the onset. The research questions and tools were jointly defined by the academic literature and by members of the target community [39] (which in this case was teenage girls). In this way, the Girls into Engineering Study placed an emphasis on the participants' perceptions and lived experiences throughout, with the participant researchers and academics mutually agreeing the interview focus and adopting a cooperative ethos [40].

Perhaps not surprisingly, CBPR has seen a surge in popularity over the past decade particularly in areas seeking to investigate the perceptions of "hard to reach" communities [41]. It was particularly useful in looking at girls perceptions of engineering as it enabled the researchers to take account of the complex nature of teenage girls' ontology and epistemology. Indeed, the two young women who

acted as researchers were particularly enthused when they realised that had a more *usual* methodology been followed the only way they could have engaged with the project would have been as 'subjects' of the research. Although, from a European perspective, it is unusual to include young people under the age of 18 years within the research process itself [42], by employing two young women in the role of participative researchers, any extant barriers reflective of age/status between the researchers and participants were automatically removed. This enabled the academic researchers to view engineering through the eyes of young women.

3.2 Methodological Process & Practice

Following the literature review, the search began for two young women able to act as participative researchers. Whilst recruiting and training two 'typical' teenage girls proved to be a little challenging for the researchers, two candidates were identified and provided with an intensive two-day long research methods training program that had been purposefully developed for the purpose of the study. Keeping the training 'researcher focused', instruction was given on basic research philosophies (with the differences between inductive and deductive approaches being discussed at some length), conceptual awareness, question writing and interviewing. Assisted by the fact that both girls were 'high achievers' who were eager to learn, the training proved successful and culminated in the construction of a qualitative interview guide which the girls developed themselves to explore the issues impacting young women's perceptions of engineering. University Ethical Approval & parental consent was obtained to employ the girls as paid ''Research Interns'' and care was taken to make sure the training, and subsequent fieldwork, not only took account of personal safety issues but also included guidance on professional behavior and conduct.

Using a purposive sampling strategy, twenty young women age 16 and 17 years were interviewed from two relatively high achieving inner city UK schools. The questions focused on girls' perceptions of engineering both as a study choice at university and also as a career option. All of the interviewees were British with four describing themselves as being from a Black or Minority Ethnic Background (BME) and the rest defining themselves as White.

The two city centre high schools are both located in the West Midlands region of the UK and are situated about 4 miles apart. The first school (School 1) is a selective girls-only Grammar School, the second School (School 2) a selective 'Church' mixed-gender School. Both schools are known locally as 'good' schools, with School 1 frequently topping national tables for academic achievement.

3.3 Analysis of Data

The interviews were recorded contemporaneously and transcribed by the young researchers. Following this a meta-analysis of the data was conducted by the two academic researchers who followed grounded theory methodology using simple and axial coding techniques. The initial process of simple coding allowed the richness and depth of the data to be thematically clustered. From there, using a process of axial coding a micro-analysis of the key emergent concepts was then undertaken by the two academic researchers working in tandem. This involved critiquing theoretically grounded relationships between concepts and sub-concepts with an emphasis being given to similarities and differences between the dimensions and properties of the topics discussed by the participants. Following this, concepts and sub-concepts were identified through a process of theoretical sampling. These concepts were discussed in some depth by the researchers who compared and contrasted key comparative themes before agreeing upon how the data should be represented [43].

Having reached a mutual agreement in respect of the key emergent themes and concepts, selective coding was used to re-analyse all the data with the researchers working in collaboration. The final stage of the analysis process involved an interpretation of the relationships and linkages between the concepts and sub-concepts in which key conceptual themes emerged from the data. The selection of verbal 'quotes' to highlight and evidence the various themes and concepts was completed at this stage. By undertaking a constant comparative analysis of the data, the process afforded the opportunity for the researchers to develop theory, grounded in data, and to identify and critique new theoretical ideas and concepts [43].

4. The Girls into Engineering Study: Interview Findings

The findings discussed in this paper relate to three of the themes identified in the analysis: Science at School—Moving from Primary to Secondary Education: Girls' Definitions of Engineering: and, Girls' Perceptions of Engineering as a Career Choice. These three themes provide useful foundational knowledge about the underpinning factors influencing young women's lack of engagement with engineering. The findings also support earlier work suggesting that girls' dislike of maths and physics continue to influence girls educational and career choices.

4.1 Tackling transition: reflections on maths & science from primary to secondary school

In planning the interviews, both of the Participant Researchers identified the transition from Primary to Secondary Education as key to how they subsequently viewed both science and maths. Such assertions supported the literature about the importance of transition, thus, in following the CPBR approach, the interviews began by exploring each participant's reflections of how they experienced science and maths at both levels.

In discussing maths at Primary School level, most of the interviewees recalled learning approaches, describing memorising their 'times tables' off by heart and generally suggesting that:

> "*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

Conversely, the girls early experiences of science suggested that they had a more 'hands on' experience, although the lessons tended to focus mainly on *nature* and biology:

> "*[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

> "*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

For most of the girls who took part in the study, the move between primary and secondary education was fraught with challenges—particularly in the way that science and maths lessons were taught:

> "*Maths, it was the same layout, but it got harder and you knew more about the specification; and 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 like in primary school, but it became more intense and more specified.*" Sonya. 16 years. School 1

> "*Maths & science got harder, I think I found them much easier in primary school where I was better at them and I went down in high school, I wasn't as good at them. They got more complicated.*" Jen. 16 years. School 1

Whilst the majority of the girls recollected that the move from primary to secondary level education was somewhat challenging in that they found science and maths lessons increasingly became a lot more difficult as they progressed, none described feeling adequately prepared by their primary school to make such a transition.

4.2 Science at Secondary Level

Whilst maths was noted to increase in difficulty between Primary and Secondary level, it was science lesson that proved particularly challenging for the girls as they changed schools. Not only did the pedagogical approach change, but the subject itself suddenly grew from a mono-discipline, to three different sciences:

> "*Science changed a lot. It became 3 sciences, whereas in primary school it was one subject of science, so it was a big change.*" Mel. 17 years. School 2

> "*In primary school it was very basic, we didn't know the difference between biology, chemistry and physics. We still do experiments like in primary school, but it in secondary school it is more intense.*" Sonya. 16 years. School 1

Having coming to terms with the fact that unlike maths, science at secondary school generally comprised three distinctive subjects, many of the girls found that they preferred biology or chemistry to physics. The reasons for this varied, but generally related to the 'hands-on' nature of the subjects:

> "*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.*" Sahar. 17 years. School 2

> "*I prefer biology because it is very relevant to everything. I suppose chemistry is as well, which I enjoy, but 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.*" 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

Notably, whilst the majority of those interviewed stated they enjoy biology and chemistry, a similar number expressed a clear dislike of physics. The reasons for this varied but generally reflected girls' opinions that physics lacks practical application and meaning, resulting in it being viewed as too abstract and theoretical in nature:

> "*I didn't really enjoy physics . . . 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 . . . It's things you can't see whereas I prefer things you can see.*" Mel. 17 years. School 2

> "*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.*" Emily. 16 years. School 1

Only three of the girls sampled 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 affects it has on it.*" Mo. 16 years. School 2

Throughout the study the girls' preference for biology linked directly into their subsequent educational choices and prospective career interests. Additionally, the 'hands-on' nature of biology was repeatedly identified as particularly appealing. It should be noted however, that whilst 'physics' was found to be the least popular science, it was not the subject itself that the girls disliked—but the way it was taught. The abstract nature of Physics Pedagogy at secondary school resulted in the girls' viewing the subject as irrelevant. Consequently, none were able to identify where studying physics could lead in terms of a future career.

4.3 What is it? Defining Engineering

Having explored the girls' perceptions of science and maths lessons at school, the interviews turned to how the sample perceive and define engineering. Over half of the girls lacked a basic awareness of what engineering is as depicted in these two typical responses:

> "*I don't know what engineering is, I think it's like making and woodwork and stuff which doesn't really interest me I don't really know much about it.*" Melanie. 16. School 2

> "*I think it's to do with inventing and structuring things? I'm not really sure.*" Danni. 17. School 2

Whilst any marketing campaigns about the possibility of engineering as a potential career for girls had clearly not had any impact on the majority of the sample, one of the young women had a clear view of how important engineering is to society:

> "*I'm not really sure how you would define it but it is very important. Society would be incredibly different to how it is now without it, because engineers are needed for all aspects of society.*" Aysha. 17 School 2

The general lack of awareness about engineering meant that most of the sample were initially reluctant to express an opinion about what they believed engineering to be. Undeterred, the two participant researchers persisted and in doing so managed to 'tease' a response out of the majority. The replies generally fitted into two distinctive categories: "Engineering is based on maths and/or science": "Engineering is about making and designing things".

In defining engineering as being linked to maths and/or science, five of the girls provided a relatively simplistic description that captured the basic underpinnings of the discipline but failed to show any deeper understanding. Indeed, in many respects, despite indicating that maths and physics are integral to engineering, this group of girls appeared to hold a somewhat traditional view of the subject, failing to connect engineering to everyday life. Some viewed engineering quite narrowly as being associated with machines, whilst others had no idea whatsoever what engineering comprises:

> "*Engineering is machines and machinery. Maybe it links with physics, but I can't see how it might with chemistry. And I can't see how it does with biology.*" Sahar. 17. School 1

> "*I don't really know [what engineering is], . . . I think engineering is just trying to work out how things are made [ ] doing the maths behind how the building's made.*" Ellen. 17. School 2

Of the twenty young women interviewed only one articulated the 'abstract' nature of engineering linking it to maths but also giving some indication that she was aware of the high level of intellectual reasoning and cognitive skills and abilities needed to be an engineer (although she wasn't able to fully communicate this):

> "*I think I'd say you need to be good at maths for it, have a good special awareness and be able to see things in your head before they are right in front of you*". Becca. 17. School 1

Perhaps not surprisingly, the most frequently voiced definition of engineering, expressed by fifteen of the twenty girls, linked it to 'designing and/or making things'. For twelve of the fifteen the concept of size was crucial, with engineering being used to describe designing or making 'big things':

> "*It's designing and making stuff. Big things. There are people who make phones and people who make cosmetics, but that's not engineering. Without engineering we wouldn't have buildings, telephone boxes [ ] you have to make sure buildings won't fall down. Which is quite important.*" Jodie. 16. School 1

> "*It's bulk industry. Engineering makes a lot of things like packaging for food, it preserves food. It cleans out water. So it's quite important really.*" Mel. 17. School 2

> "*I always think of it as building things, like roller coasters. . . Like how they work and making sure they are working well. Because you need that link between science and the things people use every day. Engineering kind of interprets science and uses it to make things.*" Sonya. 16. School 1

Only one of the fifteen described the safety aspect of engineering:

"*It's like designing something to make it better. And I think it's important because if, for example, we didn't get the curve on a roundabout right, then tall lorries would tip over. . . and drains would be overflowing.*" Roshni. 16. School 1

Another two, depicted engineering as making or designing things that are crucial to society:

"*Society would be incredibly different to how it is now without it, because engineers are needed for all aspects of society.*" Aysha. 17, School 1

"*Without it we wouldn't have half the things we have today as it provides us with a lot of things people take for granted.*" Tessa. 16. School 1

Although all of the girls seemed to be aware that engineering plays a central role in society, the majority of them appeared not to fully understand what this role is. This is not completely unexpected given that 15 of the 20 readily agreed that they don't know what engineering is about or what engineers do, a point effectively made by Carmen:

"*I'm not sure what engineering is? I'd say it's physics based. . . Engineers do a lot of technology and stuff.*" Carmen. 17. School 1

From considering how the girls defined engineering and the role it plays within society the interviews turned to the issues around engineering as a career.

4.4 Engineering as a career choice for women

Whilst the matter of gender did not figure in the girls' definitions of engineering, when asked to consider it as a potential career choice fifteen of the sample indicated that they thought engineering was a male-oriented occupation. For most of these, the issue was not that *they* thought that engineering was for men but rather that *society* viewed it as being a male occupation:

"*I think that it is seen as a masculine subject. I do know a girl that does engineering but she is the only girl in her group at university. You could say that it is male dominated.*" Danni. 17. School 1

"*I do think it is very male dominated. I wouldn't say that girls can't do it. . . most girls our age don't really hear of it, they don't really want to get into it because of the men.*" Helen. 16. School 1

For six of the fifteen girls who identified engineering as a male dominated subject, the issue was not about engineering *per se*, but was instead linked to its connection with science, physics and maths, all of which were generally perceived to be 'male oriented' subjects:

"*I think there is a stereotype that engineering is a masculine subject. But I think that this is because of the connection with physics which is a boys subject.*" Aysha. 17. School 1

"*I wouldn't say I felt I couldn't do engineering because I am a girl . . . But more boys seem to be interested in maths and science. I think engineering's just more appealing to them.*" Emily. 16. School 1

The relationship between girls' perceptions of maths and their career choices have been previously explored by Riegle-Crumb et al., (2011) who found that girls are not influenced by their *ability* in mathematics but are instead concerned with the fact that they do not *enjoy* the subject [34]. Such a lack of enjoyment may be one factor determining the participants' reluctance to consider engineering as a career choice. Whilst discussing the girls' choice of potential careers one unexpected issue emerged relating to family members who were engineers. Five of the sample had at least one parent or family member who was an engineer, with three of those having two or more engineers in the family. Noticeably, only one girl had a mother who was an engineer.

Contrary to previous studies which have identified parental role models as being key to girls' decisions to study engineering [44], those participants who had a family member who was engineer appeared not to have been influenced by this in their career choice. Indeed, despite being exposed to engineering at various times in their lives none of those with a familial link to engineering wished to pursue it as a career. The reasons for this were remarkably similar, related not only to individual choice but also to the girls' perceptions that engineering is a male dominated field:

"*I only know males that are engineers. I don't know any women despite my Dad being an engineer.*" Sahar. 17. School 2

"*When I went to Mum's office there were about 3 women and 20 men.*" Jodie. 16. School 1

"*My Dad and Brother are engineers. . .there's a few women compared to the amount of men. It's not that women can't be engineers. I just don't think females find it an appealing subject, job or career*." Ellen. 17. School 2

Although five of the girls had been exposed to engineering and engineers throughout their lives this exposure was not enough to make them want to enter the discipline themselves. The reasons for this are undoubtedly complex but this small study suggests that even when the girls do have a strong role-model who is an engineer, and are exposed to engineering from a young age, the lack of women role-models does much to shape their perspectives of engineering as a potential career or study choice. Because they don't 'see' any women engineers, they don't view it as a career for girls:

"*It's definitely masculine. I remember in Dad's place the only women there were the receptionists . . . I did think about engineering as a career, and I was very tempted to take maths and science at A level, but as I went through*

GCSEs I found out where my strengths were and I guess I realised it just wasn't for me." Tessa. 16. School 1

"*For a while I thought about becoming an engineer. When my Grandad used to talk to me about it . . . He sort of talked me out of it too, he said it was hard work but worth it. Then he mentioned physics, at which point I decided no.*" Jodie. 16. School 1

Like Jodie, half of the sample felt the link between physics and maths proved to be an added barrier to even considering engineering as a career. This, combined with a lack of exposure to the discipline for the majority of girls and a scarcity of female role models, appeared to 'frame' their overall perception of engineering as being something that girls just 'don't do'.

5. Discussion

In looking at the study as a whole, one of the key findings relates to the research process itself. The CBPR approach engendered culturally relevant data that has subsequently provided the researchers with the unique opportunity to identify the issues and begin to take steps to build capacity to address those issues [45]. Employing two teenage girls to talk to their peers about engineering proved to be a success—resulting in a unique set of data and providing the young women researchers with valuable life and work experience. From an engineering education research perspective, the approach has much potential for use in higher education. Engineering Faculties are facing unprecedented challenges, with difficulties in recruiting, high rates of attrition and gender and other inequalities [15, 16]. If we are going to get to the root of such problems there can be little doubt that a participative research approach, in which our students are trained to work as equitable partners, has much to offer.

In turning to the outcomes of the study itself, one of the key findings relates to the transition between primary and secondary education in terms of how science and maths are taught and later perceived. Maths was generally viewed as a single subject which got harder as the students progressed through school. What was notable was that none of the girls expressed an opinion about how maths could be applied in a real context. This suggests that the curriculum experienced by the girls was insufficiently contextualised within a real-world setting. The same may be said of physics, and to a certain degree, chemistry. Indeed, it was only biology that was identified as being relevant to the girls' lives and experiences. One of the most notable issues identified in the study was the difference in the way in which science was taught at primary and secondary level. In looking at the evidence presented in this study it is not unreasonable to suggest that something is clearly amiss in that children seem to lose their enthusiasm for science upon entering secondary school.

From an engineering education perspective, perhaps the most notable finding is that the majority of girls' interviewed had very little understanding of what engineering is or what engineers do. Moreover, only a couple were able to connect engineering with science, maths or technology. Given that the term STEM is increasingly part of our everyday language and is thus within the girls' ontology (as it is a term widely used in schools and in the media, see for example, TES, 2014) the failure to connect engineering to its underpinning disciplines is somewhat concerning and suggests that engineering is indeed the missing 'E'! [45].

In considering why this might be the case, it is important to note that two 'demographic' factors emerged as potentially influencing the girls' perceptions. The first of these relates to the schools the girls attended. Looking at the interview transcripts overall it seems that the girls in School 1 are more articulate and 'worldly aware' than the girls in School 2. This may be reflective of the fact that School 1 is a Grammar School, accepting only the top 5% of the population into year 7. Also School 1 is a single gender, girls only School where science and maths are heavily promoted (although it seems engineering is not). However, despite the differences between the two schools, the girls' perceptions in respect of engineering were remarkably homogenous, with neither group recognising the diversity of the discipline or its contribution to contemporary society. This in itself is a matter of concern. School 1 heavily promotes science for young women who, because the school is 'girls only' are able to learn in an environment where they are not distracted by young men. Despite this, like the girls from School 2, those in School 1 generally regarded what engineering is and what engineers do in gender-specific terms. Indeed, whilst most of the participants from both schools thought girls could do engineering if they wished, they also viewed it as an occupation for men.

The second notable demographic factor relates to ethnicity—in looking at the data as a whole, ethnicity did not appear to impact the girls' perceptions or answers at all. Indeed, if anything, their views suggested a mono-culture whereby all of the girls held similar views. This may be reflective of the multi-cultural nature of the city where the study took place (where 20% of the population are of a non-white background). Despite their demographic and educational differences, the girls' perspectives were remarkably similar. Unless they had a family member who was an engineer, they knew little or nothing of the discipline and had not considered it as an option for themselves.

In considering why the girls appeared to have little or no knowledge of, or real interest in, engineering, it is important to note that when asked to think about what engineering was, the majority articulated it from a functional or applied perspective. To them engineering was about 'making or designing things' or 'making things work'. This perspective may be indicative of the geographic location where the study took place, where around 10 years ago many people (mostly men) were employed in what was known locally as 'heavy engineering' (manufacturing industries). The recent recession, manifested by mass redundancies and industrial closures across the region undoubtedly contributed to the girls' negativity and nonchalance—many of them would have grown up hearing their fathers, brothers and uncles asserting that 'engineering is dead' in their particular corner of the world!

Another notable factor relates to the fact that the girls who were able to link engineering with maths appeared to view such linkages negatively. That only two referred to the 'creative' nature of engineering leads to the suggestion that the discipline as a whole, and University Engineering Programmes in particular, have much to do to promote engineering as a viable and attractive option for girls.

6. Recommendations for Policy Makers, Teachers & Engineering Education Researchers

This study has led to five distinctive recommendations being made.

6.1 Recommendations for policy makers

- The question of when children should be exposed to STEM within the curriculum has been the subject of debate for some time (see for example, IMECHE, 2010 [46]). In considering this issue, the paper writer's suggest that engineering needs to be become part of everyday language at both primary and secondary level—with children being exposed to 'active learning experiences' in engineering similar to those in biology from an early age.
- The Perkins Review (DBIS, 2013) drew attention to the role played by STEM Education in schools in preparing young people to study engineering [47]. In taking the findings of this report one stage further policy makers need to make sure that 'engineering' is given due consideration; particularly at secondary school level. Engineering forms an important part of the applied science portfolio, linking science and society, providing a bridge between the humanities and science. The curriculum needs to reflect this.

6.2 Recommendations for teachers

- The main issue with physics was noted to be how the subject is taught. Physics teachers need to take a more applied pedagogical approach. Making young people aware not only of how physics is used in the real world, but also highlighting which careers it could lead to (including engineering)
- Secondary level science teachers could look to their colleagues at primary level for examples of how to teach all three of the sciences in a more applied and holistic manner. Whilst there is clearly a need to separate the sciences at secondary level, young people need to be made aware of the interlinked nature of the STEM subjects.

6.3 Recommendations for engineering education researchers

- The Community-Based Participatory Research approach in this study proved a useful and practical method of accessing a 'hard to reach' segment of the population. In seeking to explore the underpinning theoretical and conceptual aspects of various educational phenomena Engineering Education Researchers need to leave their 'comfort zones' and adopt a more participant-friendly approach such as CBPR.

7. Conclusion

In conclusion, the main issue to emerge out of this study is the need to provide girls with a clear message about what engineering is and what engineers do. The negative connection that the girls make between engineering and physics and maths needs to be addressed, so that instead of being seen negatively, physics and maths are seen as positive choices which could lead to a wonderful career in engineering. Engineering has much to offer young women, the problem, as this study has shown, is that they simply don't know it.

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