ATTITUDINAL AND PHYSICAL BARRIERS AGAINST WOMEN WITHIN THE HIGHER EDUCATION ENGINEERING CURRICULUM

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ABSTRACT

It is a well-known fact that there is a significant disparity in not only the proportion of sex, but the overall experience that each sex faces within the engineering sector. Research has shown that barriers against women to succeed to their full potential within the industry stems back to the environment and curriculum created within the education system, particularly of technical subjects. I wanted to delve deeper into this theory, and see if it rings true for engineering degrees within higher education- particularly focusing on the Engineering Science Department at the University of Oxford. In this paper, I investigate the reasons why implicit biases exist within engineering at higher education and how they have formed within Oxford's very own Engineering Department- focusing on the curriculum and environment created during the late 20th century (1975-2000). I also compare these findings with statistical analysis done on graduate theses submitted from the Engineering Science Department (within the same time period). Biases were found within the curriculum- particularly surrounding teaching and assessment methods, but also by making assumptions on a student's learning experience and background before looking at the true pool of students. While the department managed to spot some of the biases they have formed, and hence acted to prevent them for the future, there are also many instances where they have failed to provide an inclusive environment for women to study- and is hence reflected in the number of theses submitted by women at the time. I also look into why women are more likely to not join the engineering industry (or research) after completing their degree, and what steps the department needs to take, in order to reduce this effect.

Introduction

It is a well-known fact that even today, there is a distinct discrepancy of sex within the engineering sector. Research done this year by EngineeringUK shows that in 2021 women only accounted for 16.5% of people working in engineering roles.[1] On one hand this percentage has increased over the past 50 years (from around 1% in the 1970s), however, especially in recent times, the rate of increase of women in engineering is slow, and has been declining.[2] Contributing to this discrepancy are the combined obstacles of misconceptions, stigmas, and sexist behaviours in the workplace, painting engineering to be a 'dirty' and inappropriate career for women to choose.[3] Although, particularly in Western society, a lot of these beliefs turn out to be untrue at present, surveys, and interviews from the 1980s and 1990s suggest that these misconceptions were once true, and in the not-so-distant past. Drawing from these surveys, at the time it was strongly believed that 'technological competence correlates strongly with masculinity and incompetence with femininity'.[4] This thought often came into fruition, as female engineers within the workplace often got given 'women's job' (such as photocopying) over technical work.[5] As one can imagine, these types of behaviours have a lasting impact in how a woman perceives self-confidence (often associating it with outside the workplace) and their retention rate within the industry.[6]

More often than not, a lot of these viewpoints are introduced to women at a young age, particularly through school. One point that is often overlooked in society and particularly in the workplace is how significant of a role education plays within making or breaking a woman's potential career in engineering. For example, at secondary school level, technical subjects such as physics are often presented as 'male' subjects and hence many secondary schools (particularly co-educational schools) face under subscription of girls to the A-Level Physics course.[7] This issue increasing during higher education, where men far outnumber women in applications for courses such as physics, computer science and engineering.[8]

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1 EngineeringUK, "Women in Engineering: Trends in Women in the Engineering Workforce between 2010 and 2021: Extended Analysis," *Engineeringuk.com* (EngineeringUK, March 2022), 2, https://www.engineeringuk.com/media/318036/women-in-engineering-report-extended-analysis-engineeringuk-march-2022.pdf.

2 Shulamit Kahn and Donna K. Ginther, "Are Recent Cohorts of Women with Engineering Bachelors Less Like to Stay in Engineering?", *Frontiers in Psychology 6*, no. 1144 (August 19, 2015), 2, https://doi.org/10.3389/fpsyg.2015.01144.

3 Catherine Hood et al., "Girls and Technical Engineering: A Report of the Pilot Programme to Encourage More Girls to Consider Becoming Technicians in Engineering" (Watford: EITB, 1984), 13-18.

4 Carol Jones, "Becoming 'One of the Boys': Female Engineers in the Electronics Industry", *Women: A Cultural Review* 3, no.1 (June 1992): 72, https://doi.org/10.1080/09574049208578109.

5 Carol Jones, "Becoming 'One of the Boys': Female Engineers in the Electronics Industry", *Women: A Cultural Review* 3, no.1 (June 1992): 73, https://doi.org/10.1080/09574049208578109.

6 Lotte Bailyn, "Experiencing Technical Work: A Comparison of Male and Female Engineers", *Human Relations* 40, no. 5 (1987): 304, https://doi.org/10.1177/001872678704000504.

7 Sharon McGuire, C.J Laidlaw, and Engineering Industry Training Board, *Women in Engineering: Trends in Employment and Training* (Watford):Engineering Industry Training Board, 1987), 30-31.

8 University of Oxford, "University of Oxford Admissions Report" (Oxford: University of Oxford, May 2022), 19-21 https://www.ox.ac.uk/sites/files/oxford/AnnualAdmissionsStatisticalReport2022.pdf.

There are further attitudinal (and some physical) barriers to women pursuing engineering in Higher Education in both the curriculum and learning environment. Work done by Powell, Bagilhole, Dainty and Neale in the early 2000s shows that a significant number of women leave the engineering community once finishing their degree, and don't pursue any further career in the area.[9] This emphasizes the importance of assessing and changing the educational environments of women in STEM in order to improve their retention in engineering careers.

I have hence chosen to focus my project on the attitudinal and physical barriers within engineering higher education, particularly within Oxford, against the female sex (between 1975-2000).

For a quick disclaimer, I think is worth noting on my use of the term 'sex' in this context. Due to the time range of where most of my sources are pulled from, and for privacy considerations, I can only categorise the binary terms men and women as people's legal sex. This therefore may not concur with someone's gender identity.

Engineering in Higher Education

Powell, Bagilhole, Dainty and Neale highlight how the culture created within the engineering industry is 'mirrored in the engineering classroom' mostly through sexist behaviour that is dismissed by male students and teachers as 'banter'.[10] This often creates an intimidating and uncomfortable environment for women to learn in, affecting their self-confidence and setting an expectation that women need to conform to the more 'masculine' environment and become 'one of the boys' in order to succeed. This is obviously not the case for everyone, as some of the women's accounts in the article mentioned male course mates who were 'really friendly and helpful', and male teachers that were very 'supportive' and 'motivating' towards their students, but it is impossible to deny the accounts of people conveying the power of gender imbalance within the HE sector. I say people as there were even some accounts of female teachers, at different levels in education, who turned a blind eye to (or even joined in with) the discrimination that women were experiencing when studying technical subjects.[11] This can be particularly damaging, as on the face of it, these teachers present themselves to be a role model for female students, but their failure to provide sufficient support can make them feel more isolated and make it harder for them to learn in such an environment.

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[9] A. Powell et al., "Does the Engineering Culture in UK Higher Education Advance Women's Careers?," *Equal Opportunities International* 23, no. 7/8 (October 2004): 21, https://doi.org/10.1108/02610150410787882.

[10] A. Powell et al., "Does the Engineering Culture in UK Higher Education Advance Women's Careers?," *Equal Opportunities International* 23, no. 7/8 (October 2004): 30-34, https://doi.org/10.1108/02610150410787882.

[11] Ruth Carter and Gill Kirkup, *Women in Engineering: A Good Place to Be?,* ed. Jo Campling, 1st ed. (London: Macmillan, 1990), 52.

However, environment is not the only factor that favours cis-males. Research done by Mills and Ayre shows how the content within the engineering curriculum itself is peppered with implicit biases that may be missed by first glance.[12] Unsurprisingly, many engineers disagreed with this concept arguing that 'their curriculum content is based on universal laws, and is not therefore subject to cultural or gender bias', but failed to recognise that the methods of these laws are solely Western based, created by white cis-men, and when building a curriculum, an assumption is usually made on the students that they can reach an equivalent mindset. Without getting too rooted into the issues surrounding the colonisation of science (as that can be multiple papers in itself), understanding how colonial science has affected education in Western society gives us an invaluable perspective- a curriculum is based on assumptions made on a student's mindset, when they don't know who the student is, and the environment they are learning in. Work done by S. Lewis explains how 'research questions, methods, criteria of success, and styles of teaching are male defined, and consequently, the knowledge itself reflects a bias towards a male cognitive style in its practices, theories and ways of teaching'.[13] This very much highlights how educators assume students naturally reach the mindset of a white cis-man as it exposes the lack of representation of teaching staff within engineering academia itself. It shows that along with using theories and methods from white cis-men from the 17th, 18th and 19th centuries, there is only really one type of person that an engineering board can go off of when trying to assume a potential students mindset.

It is also worth mentioning the nature of the engineering workplace vs HE. In HE a disproportionate amount of emphasis is put on 'purely technical activity' and theoretical mathematical and physical concepts, and barely puts emphasis on real-life engineering practice, which focuses a lot more on social cues, ideologies, and relations.[14] This way of teaching, which aims to take social values out of the question (potentially to avoid risk of 'cultural or gender bias') serves to discourage students from taking it as a career, particularly potential students that hold a broader range of interest and hold values outside the engineering bubble. Too often this tends to be women, as research shows women are more likely to value success outside of engineering.[6] Unlike their male counterparts, women's self-confidence is often strongly correlated with their perceived success outside of the technical field, rather than with their technical expertise. This is likely due to the sexist views of how

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[12] Julie Mills and Mary Ayre, "Implementing an Inclusive Curriculum for Women in Engineering Education," *Journal of Professional Issues in Engineering Education and Practice* 129, no. 4 (October 2003): 206, https://doi.org/10.1061/(asce)1052-3928(2003)129:4(203).

[13] S. Lewis, "Chilly Courses for Women? Some Engineering and Science Experiences in Women, Culture and Universities: A Chilly Climate?" (Sydney: University of Technology, 1995).

[14] Sharon Beder, "Towards a More Representative Engineering Education," *International Journal of Applied Engineering Education* 5, no. 2 (1989): 174, https://www.researchgate.net/publication/295410033_Towards_a_more_representative_engineering_education.

engineering is not a ‘feminine’ path and hence may be strayed from family related responsibilities.[15]

Time Period

When looking at this topic, and at general statistics of women going through education choosing technical subjects, what struck me was the amount of research on it throughout the last quarter of the 20th century. The research I have mentioned above have all come from the 1980s, 1990s and the very early 2000s (with the latest published work referenced dated to 2004). There seemed to be a clear initiative to increase the proportion of female students in engineering within this time period, which made me question, what pushed the engineering community to finally turn their focus on making the industry and the education sector more diverse?[16]

One factor could be The Sex Discrimination Act of 1975, a law put into place in Britain to ensure that no one was discriminated against, in any aspect of life, regardless of their sex.[17] In the realm of sex discrimination within education, Part III Section 22-28 made it illegal to discriminate against a woman on ‘offers to admit her to the establishment as a pupil [...] refusing or deliberately omitting to accept an application for her admission to the establishment as a pupil’. It also became unlawful to refuse any facilities to a woman or benefit or disadvantage her deliberately based on her sex.

As a result, it is very interesting to look at the adjustments made to accommodate women in male dominated technical subjects within HE over the last quarter of the 20th century and how this had opened up such a huge research route.

Brief History of Women (Particularly in Engineering) at Oxford

As a student at the University of Oxford with first-hand experience of being a non-cis male engineering student in the present day, it only made sense that I chose to focus on this social change within the context of Oxford. Therefore, it is worth going over a brief and general history of women not only in Oxford as a whole, but also looking particularly at the engineering department in particular throughout the 20th century.

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[15] Lotte Bailyn, “Experiencing Technical Work: A Comparison of Male and Female Engineers”, *Human Relations* 40, no. 5 (1987): 306, https://doi.org/10.1177/001872678704000504 .

[16] Sue Peacock, Catherine Eaton, and Engineering Industry Training Board, Women in Engineering: EITB Initiatives ([Watford?]: Engineering Industry Training Board, 1987), 3–26.

[17] UK Government, “Sex Discrimination Act 1975,” Legislation.gov.uk, 2011, https://www.legislation.gov.uk/ukpga/1975/65/enacted.

When the University of London started to officially admit women into their classes and award them with degrees in 1878, the first university to do so in the UK, Oxford looked at this idea with a great deal of hostility. This was mainly due to the fact that they were scared

that opening up admissions would mean that 'men would be lured into an early marriage and would no longer be able to establish themselves in a desirable or lucrative career, which could only be achieved by a young man in his twenties who was focused and celibate'.[18] This in hindsight is a ludicrous statement, but in the societal norms of the time, was something that was generally believed. However, this did not stop the movement of women's education in Oxford, and the first female college (Lady Margaret Hall) was founded in 1879 with three more women's colleges being opened before the end of the century.[19] Even though women were becoming integrated within the University's society, it was not until 1920 that they were finally allowed to matriculate, take degrees, and become members of congregations and faculty boards. This huge change was largely due to the country's great reform on societal equalities at the time.[20]

However, the Engineering Science Department would not see its first female graduate until 1939. This was Anne Pellew who was affiliated with St Hugh's college. There was a research assistant at the department around 10 year prior however, as Letitia Chitty was part of the research team that Richard Southwell led (working on developing mathematical methods for engineering problems).[21]

The 1970s saw the biggest change with Oxford's attitude towards sex. The first five all-male colleges became co-education in 1974, as to test the waters, but it was not until 1979 that most other male colleges (as well as two of the five established female colleges) followed suit. This was mainly due to a moratorium that was still in place, but most college heads decided to break it as it made Oxford look both legally and socially out of line.[22] At this point, women accounted for less than 7% of the class lists in Engineering, however, this grew and by 1989 the statistic was more than 20%.[23]

By 2000, five women held university posts within college fellowships in Engineering.[24]

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[18] L.W.B Brockliss, *The University of Oxford: A History*, 1st ed. (Oxford: Oxford University Press, 2016), 373.

[19] L.W.B Brockliss, *The University of Oxford: A History*, 1st ed. (Oxford: Oxford University Press, 2016), 373-378.

[20] L.W.B Brockliss, *The University of Oxford: A History*, 1st ed. (Oxford: Oxford University Press, 2016), 390.

[21] A.M Howaston, *Mechanicks in the Universitie: A History of Engineering Science at Oxford* (Oxford: Department of Engineering Science, 2008),83.

[22] L.W.B Brockliss, *The University of Oxford: A History*, 1st ed. (Oxford: Oxford University Press, 2016), 572-573.

[23] A.M Howaston, *Mechanicks in the Universitie: A History of Engineering Science at Oxford* (Oxford: Department of Engineering Science, 2008), 138.

[24] A.M Howaston, *Mechanicks in the Universitie: A History of Engineering Science at Oxford* (Oxford: Department of Engineering Science, 2008), 83,

Analysis of Oxford Curriculum 1975-2000

The history above barely scratches the surface of capturing the experiences of women studying engineering at Oxford within the time period of 1975-2000, let alone gives any indication of how the department's decisions on the curriculum can contribute to any of the hardship they faced. I realised the best way for me to obtain a true sense of any biases that may have occurred was to go to the source itself and look at the Oxford Archives for documents within the Engineering Department during the late 20th century. I was particularly looking at any discussion on course and assessment as well as any discourse on the environment felt for their students.

The archive 'OUA/FA 3/8/1/4- Agenda, minutes and papers of Engineering Sub-faculty meetings (1989-1993)' particularly grabbed my attention- mainly due to how well I was able to paint a picture of how the department not only created biases, but also recognised some of them, trying to find solutions to combat the barriers they made.

As mentioned earlier in this paper, one thing that kept cropping up when reading into this research topic was the preference among practical based learning vs theoretical/lecture type learning for women in engineering higher education. This is most likely due to the fact that as engineering is the application of physical and mathematical principles into the real world (at its core), a more practical heavy curriculum is what they expect when applying to university. However, the importance of practical work may not have been fully recognised by the department during the 1980s and 1990s as during a sub-faculty meeting in October 1990, a committee member, Dr Turnbull, made a comment saying 'I was struck by the way the marks, allocated from the 'practicals', distorted the distribution of marks in each of the core papers and how they artificially raised the average mark of these papers [...] The practical work marks are no longer added to the core papers' and also commented on 'for the two Engineering and Society essays, may be excessive'.[25] The comments that he made highlighted the desire to remove the influence of practicals within the curriculum and make it more theory based. In fact, compared to today, practical work does not have much influence at all on a student's mark (only accounting for half a paper, with 4 theory papers, for the first two years of the degree and only makes up a significant proportion of the grade in the 3rd and 4th years). Research suggests that men typically prefer a more lecture and theory-based style of teaching and hence an implicit gender bias may have been an influence in this comment

[25] Sub-faculty of engineering science, "Items for the meeting held on the 25th of October 1990" *OUA/FA 3/8/1/4* Oxford: University of Oxford, 25th October 1990.

and in the decision making as well.[26] It is also worth noting the second part of his statement regarding the 'excessiveness' of the Engineering and Society essays. I thought that this was interesting as Turnbull's preferences lessens the importance of understanding how engineering integrates with society and puts more emphasis on mathematical and physical theory. This is concerning as a huge part of the engineering industry is fitting projects around general society, politics, and economics. Not adequately preparing engineering students for the industry may be a reason women leave the sector early or pursue something else after HE.

Although we have just seen an example of the department unknowingly putting barriers up against women's education in engineering, some cases conveyed the department taking positive action against assumptions made on students. Within the Report of Academic Committee on Examination Papers, 1989, during the discussion of Mods, the board discusses their realisation that they made the Dynamics and Electricity sections of the papers too difficult stating 'We tend to assume a considerable knowledge of dynamics, but some students come to us knowing virtually nothing [...] Again we tend to assume knowledge which is not there'.[27] These statements show how when creating a curriculum, the faculty assumed a certain standard of student without properly looking at its pool of current and prospective students. A reason for this assumption could be, they only looked at a small pool of sixth form education (most likely independent boy schools as they would be where the largest proportion of applications were from) and saw their curriculum, not fully taking into account that some incoming students, particularly from schools with less funding and facilities, would not have the opportunities to learn certain subjects in the depth that was first assumed. This type of discussion was continued in a Sub-faculty of Engineering Science meeting held in May 1993 when during the 1992 Moderations 'a substantial number of candidates obtained unsatisfactory results' and as a result 'Positive action is required to ensure a smooth transition from school to our first-year course'.[28] This action came in the form of tutorial sheet style work that would be given to incoming students within the long vacation before their first year and was made to help these students 'not become discouraged in the first few weeks'. This is particularly interesting to see the beginnings of a process that has an impact on me as when I joined Oxford in 2020 (27 years later) I had to complete the introductory work set before arriving here. This decision conveys how the department recognised that not everyone finishes their A-Levels on the same footing and with the same experience and facilities. And although not a perfect solution, it is a good measure to make

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[26] Lisa M. MacLean, *Cracking the Code: How to Get Women and Minorities into STEM Disciplines and Why We Must*, ed. John K. Estell and Kenneth J. Reid, 1st ed. (2017; repr., New York: Momentum Press, 2017), 42, https://ebookcentral.proquest.com/lib/oxford/reader.action?docID=4791046.

[27] Academic committee of the sub-faculty of engineering science. ''Report of Academic Committee on Examination Papers (Engineering Mods and Finals 1989)'' *OUA/FA 3/8/1/4* Oxford: University of Oxford, 26th October 1989.

[28] Sub-faculty of engineering science. "Sub-faculty of Engineering Science Agenda- for the meeting to be held on 13th May 1993 at 2.15 in LR2" *OUA/FA 3/8/1/4* Oxford: University of Oxford, 13th May 1993.

sure that everyone is able to reach a certain level of understanding of Maths and Physics concepts (including dynamics and electricity) before starting their first term.

Moving back to the environment created in HE, women felt an uncomfortable air when they were in a learning setting (particularly during tutorials). This issue was directly raised by the board in an Undergraduate Liaison committee meeting held in June 1991. 'women students had disproportionately worse results in final honour schools than men, based on statistical studies of final results since 1984 [...] Tutorial methods used in Oxford were very confrontationary and women may feel very intimidated by such methods and their work may suffer as a result [...] the exam structure being at fault rather than teaching methods or the subject itself'.[29] They found that women performed perfectly fine during term time, submitting work on par with their male counterparts. It very much proved that the reason that women performed worse in exams on average was not because they don't know the curriculum, they very much do, but external and psychological pressures meant they felt that they had to work harder to achieve the same grades. Drawing back on her work, Carol Jones argues that even outside of a university context women typically feel significantly less confident than their male counterparts in high pressure situations.[30] This is probably due to implicit sexism in society, something that is still trying to be undone today. It is still a relatively new concept to trust a woman's competency in technical related work (such as engineering) as it has for the longest time been perceived as a male domain, and hence women feel less confident in their knowledge.

One more source from this archive that I would like to comment on is the University's response to recommendations for graduate level in HE. Focusing specifically on recommendation three 'Part-time MSc. This does not directly affect us as we have at present no taught MSc courses' and recommendation six 'As we have no provision for part time [PhD] students, this will not affect us'.[31] The University essentially states how they do not offer any part-time graduate courses and that they do not intend to. Especially at the time of 1975-2000, a significant reason women did not pursue graduate research was due family commitment (the ideology that women should stay at home to look after the children whilst their husbands were considered the 'breadwinners' were still heavily rooted in society at the time) and hence they didn't have the time to commit to full-time university research.[32]

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[29] Undergraduate Liaison committee for engineering science and joint courses with engineering. "Undergraduate Liaison committee for engineering science and joint courses with engineering minutes of the meeting held on Tuesday 4th June 1991 at 2.15pm" *OUA/FA 3/8/1/4* Oxford: University of Oxford, 4th June 1991.

[30] Carol Jones, "Becoming 'One of the Boys': Female Engineers in the Electronics Industry", *Women: A Cultural Review* 3, no.1 (June 1992): 73,https://doi.org/10.1080/09574049208578109.

[31] Sub-faculty of engineering science. "Memorandum" *OUA/FA 3/8/1/4* Oxford: University of Oxford, 19th April 1993.

[32] Shulamit Kahn and Donna K. Ginther, "Are Recent Cohorts of Women with Engineering Bachelors Less Likely to Stay in Engineering?," Frontiers in Psychology 6, no. 1144 (August 19, 2015), 14, https://doi.org/10.3389/fpsyg.2015.01144.

However, if Oxford did offer part-time graduate study, then this may have opened access to mothers who wanted to pursue research but did not have the opportunity to pursue it full-time.

Theses Done By Women in Oxford between 1975-2000

Methodology

I wanted to look at this final point on women doing graduate studies in closer detail. It is interesting to see whether (particularly in the first half of the period 1975-2000) these traditional mentalities on sex can be translated to the proportion of women submitting theses. Also, as we travel through the rest of the 20th century, as I mentioned earlier, it would be intriguing to see whether the transition towards views of equality on sex can be reflected within this data. Graduate thesis publications give a very good indication of not only the proportion of sex entering academia (as this is a genuine problem in itself with a disproportionately higher number of men entering the pathway vs women) but also gives an estimate of the retention rate of women continuing engineering further from HE and which type of engineering they are most interested in. Being a university student and having open access to library databases, makes the process of finding published theses significantly easier and quicker than searching through closed archives to see if there are any tables or statistics on the sex distribution of undergraduate entry.

In order to paint a full picture on the proportion of women submitting theses from Oxford within the late 20th century, I decided to conduct two type of comparisons. The first being an external one. Here I compared theses submitted from late 20th century Oxford (sourced from SOLO) to theses submitted from King's College London, University of London (KCL) in the same time period (sourced from ProQuest Dissertations & Theses Global).[3334] Doing a cross-comparison between different universities within the same time period gives us a third person insight of how receptive Oxford's Engineering curriculum is to change in social view around sex on a grander scale (not just looking at the change within itself over those 25 years). I chose to do this comparison with KCL as, not only did ProQuest have the most similar size database to SOLO for the late 20th century Oxford search, but it is also part of the University of London- the first university in England to allow women to officially take classes and be awarded degrees.

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[33] Bodleian Libraries, "Advance Search," solo.bodleian.ox.ac.uk (University of Oxford, July 11, 2011), https://solo.bodleian.ox.ac.uk/primoexplore/search?vid=SOLO&lang=en_US&sortby=rank.

[34] ProQuest, "Advance Search," ProQuest Dissertations & Theses Global (ProQuest, 1997), https://www.proquest.com/pqdtglobal/index?accountid=13042&parentSessionId=wmkjIfiYh87TIj8Jkdo%2Bws5szjFQspkKOx3LlOP7k6s%3D.

The second comparison I conducted was an internal one. For this I compared theses from 20th century Oxford to theses from present day Oxford (the time period specifically is 2017-2022, and these theses were sourced from SOLO). The point of this comparison is to observe the progression of inclusivity towards women internally. This can give us an indication of whether Oxford has been able to create a more comfortable space for women to study and research as well as see the rate at which these improvements occur (by looking at sharp raises in the number of women submitting theses). Looking at data from the past five years also gives us a good springboard to bounce off for further research in diversity within HE curriculum.

To find the theses specifically: For SOLO, I did an advanced search where I specified the subject to be Engineering, the resource type to be Theses (Oxford) and the language to be English. Once this loaded, I then put a date range of 1975-2000/2017-2022. For ProQuest, I again did an advanced search for Engineering, then once it loaded I specified the date range to be 1975-2000 and then specified to include King's College London, University of London within the Universities/Institutions section.

When tabulating the data, there were seven columns I chose to include: 'Name', 'Sex', 'Year', 'Dept.', 'Title', 'Main Topic' and 'Thesis Type'. The most important columns for analysis were 'Sex', 'Main Topic' and 'Thesis Type' as they shaped the main categories. 'Year' also played a significant role as it displayed progression. In the end, Table 1 (late 20th Century Oxford) had 150 entries, Table 2 (Present Day Oxford) had 87 entries and Table 3 (late 20th Century KCL) had 150 entries. The spreadsheet for analysis is also available to view (linked next to this PDF). I highly recommend reading it in conjunction with the 'Analysis of the Results' section below as I limit myself to discussing only the main groups of analysis.

One of the biggest challenges when collecting this data was distinguishing the sex of some candidates. This was particularly apparent for the entries for Table 3 (Late 20th Century KCL), as most of the names presented in ProQuest gave first initials instead of full names. This also occurred within Table 1 (Late 20th Century Oxford) but to a much lesser extent. In addition to this, there were some names with which I was unfamiliar. However, researching on the internet as well as looking at the acknowledgement sections, I managed to associate a good proportion of the names with a sex. In Table 1 (Late 20th Century Oxford), there are only 11 entries where the sex could not be identified, in Table 2 (Present Day Oxford) every entry was identified, and in Table 3 (Late 20th Century KCL) there are 48 entries where the sex could not be distinguished. This means that many analyses could not be fully comprehensive using the given data and could be subject to change if more information on

these unidentifiable candidates were available/found. One other challenge that I faced when collecting the data was distinguishing some of the types of engineering that theses were written on. This particularly occurred more specifically with Table 2 (Present Day Oxford), naturally, as research topics have become more advanced and integrated with other fields, it is slightly harder to distinguish the candidates general field, when some titles were so niche. Having said this, I managed to classify all the topics and I mention this to make the reader aware that some of the theses may fall in multiple categories.

Analysis of the Results

Table 1 (Oxford Theses 1975-2000)

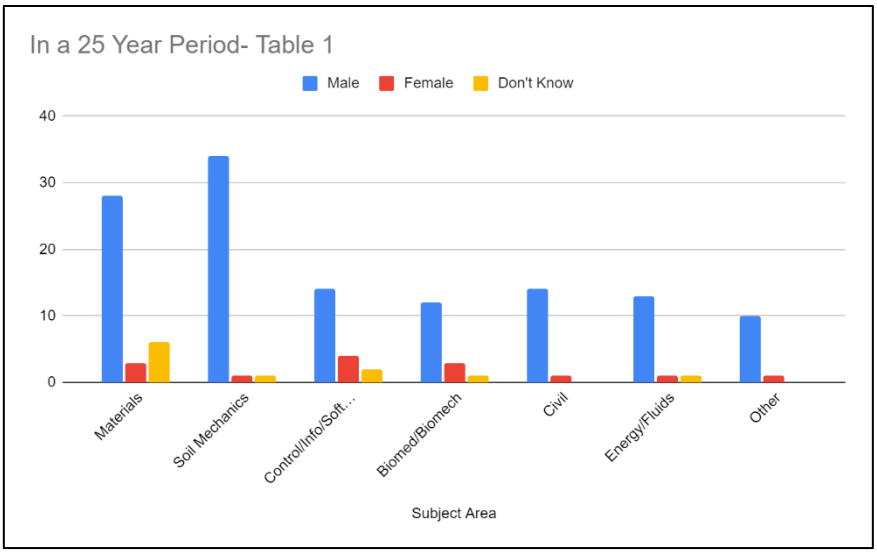


Fig 1: Distribution of Sex of Thesis Submission from Table 1 over the 25-Year Period

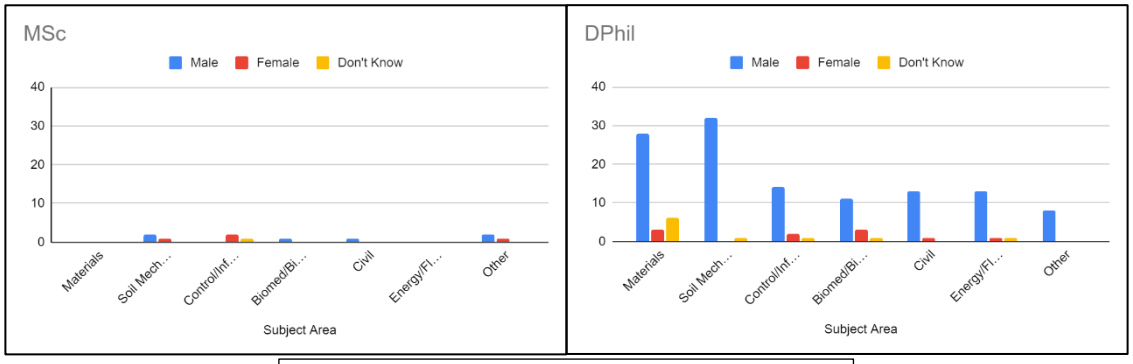


Fig 2: Distribution of Sex of Thesis Type from Table 1

Table 1 had 150 entries overall- 125 Male, 14 Female and 11 Unknown Sex across the 25-year period. This means that out of the 150 entries, only 9.33% were known females (and out of the total of known males and females, 10.07% were known females). The overall three most popular types of engineering for research (for both sexes combined) were Materials (with 37 theses submitted- all of which were DPhil theses), Soil Mechanics (with 36 theses submitted- three MSc theses and 33 DPhil theses) and Control/Info/Software (with 20 theses submitted- three MSc theses and 17 DPhil theses).

Even though Soil Mechanics was the second most popular subject to research, it was certainly not popular amongst women, with by far the lowest proportion of women submitting theses for the subject (only 1 known female submission, and only one entry with the sex unknown). This leads to the proportion of known females taking the subject to be less than 3%. It is also worth noting that the singular known female entry was an MSc submission.

However, in contrast, the third most popular research subject, Control/Info/Software, had the highest proportion of thesis submission by women- with 4 out of the 20 entries being known females (and only 2 entries with the sex not found), leaving a percentage around 20% mark. In terms of type of submission, the known females (as well as the entries who sex is unknown) have a half split, with 2 (or in the second case, 1) entries for both MSc and DPhil. Although out of the top three subjects, this has the highest proportion of females submitting DPhils, it is worth noting that all of the known male entries submitted DPhils.

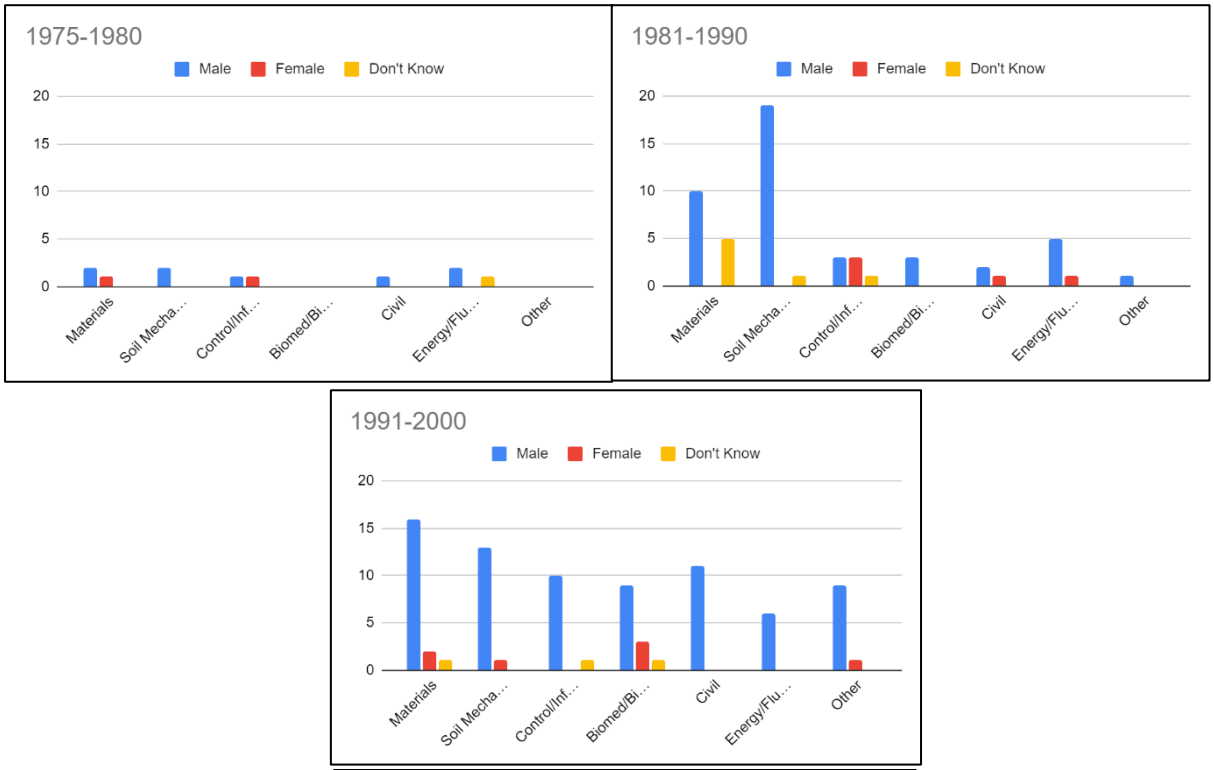


Fig 3: Distribution of Sex of Thesis Submission from Table 1 per Decade

Separating the data into decades, we can see that there is a steady incline of the number of women submitting theses. As expected, most of the known female submissions were done within the last decade (1991-2000), with 7 out of the 14 known female submissions and the subject with the highest number of female submissions in this decade was the Biomed/Biomech group.

Table 2 (Oxford Theses 2017-2022)

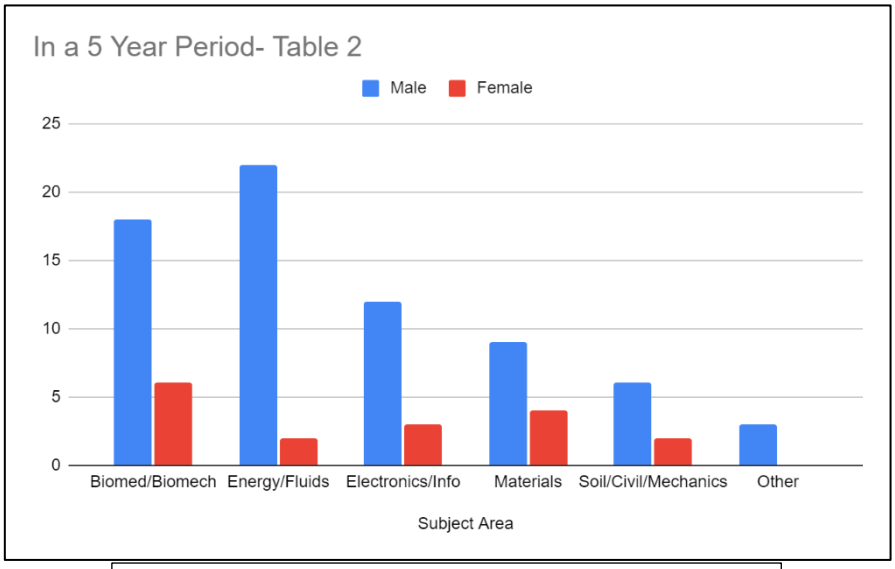


Fig 4: Distribution of Sex of Thesis Submission from Table 2 over the 5-Year Period

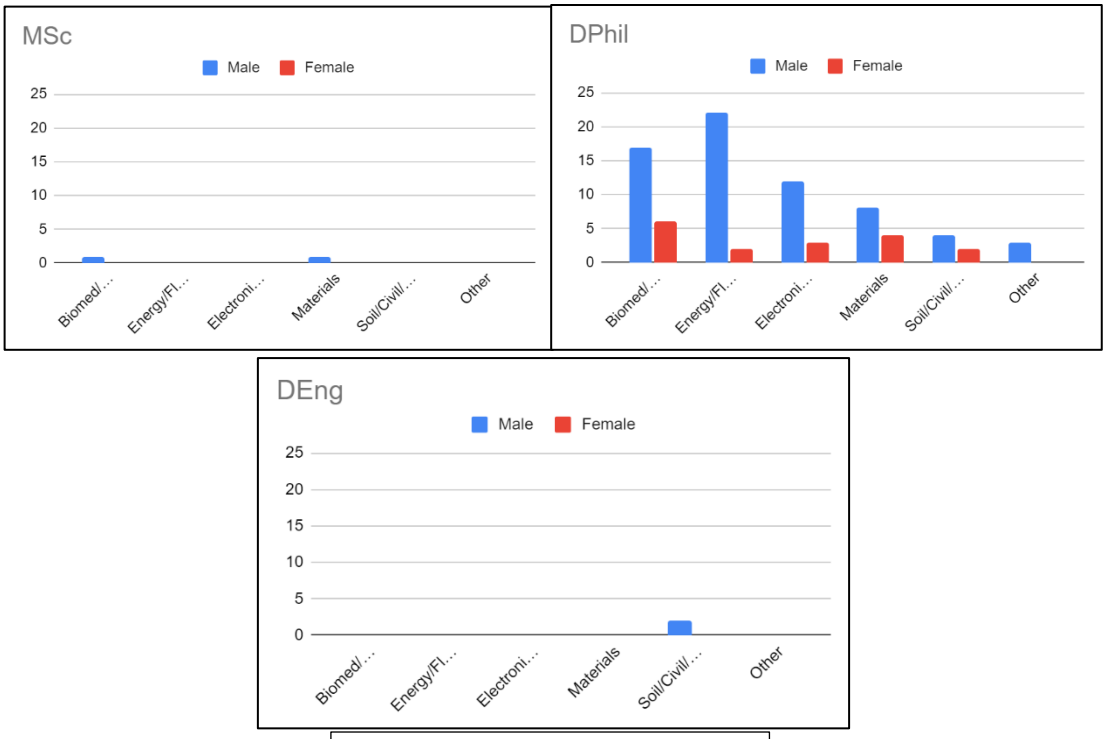


Fig 5: Distribution of Sex of Thesis Type from Table 2

Table 2 had 87 entries overall- 70 Male, 17 Female and 0 Unknown Sex across the 5-year period. This means that overall, 19.54% of the entries were female. The three most popular types of research subjects (for both sexes combined) were Biomed/Biomech (with 24 theses submitted- 1 MSc thesis and 23 DPhil theses), Energy/Fluids (with 24 theses submitted- all of which were DPhil theses) and Electronics/Info (with 15 submitted- all of which were DPhil submissions). Overall, there were only two MSc submissions, both of which were by men (all female submissions were DPhil). However, it is worth mentioning the introduction to DEng thesis submissions. DEng's are effectively DPhils but with solid links to the engineering industry and focus on engineering practice rather than theory. It also

tends to be a qualification done mid-way through one's engineering career (funded by the company). This table finds two DEng submissions in Soil Mechanics (and hence in the Soil/Civil/Mechanics subject group) both of which were done by men.

Materials actually saw the highest proportion of female thesis submission over the other subject areas (with 4 out of the 13 entries being female (30.77%)) and is the other group for an MSc entry (as I stated above, it was done by a man). However, I also want to draw attention to the Biomed/Biomech group, as not only was it the popular subject overall, but the subject area also saw the second highest proportion of female thesis submissions (25%) as well as the highest number of submissions within the female entries (6 out of the overall 17 women submitted theses in this subject grouping).

Looking at the other side, the subject area that had the lowest proportion of female submissions (after my 'Other' category) is the research done in Energy/Fluids (where 2 out of the 24 entries were women- 8.33%). All submissions were for DPhils.

It is also worth mentioning that the sample size for Table 2 is, understandably, smaller and that we are working with a time period that is a 5th of the size.

Table 3 (KCL Theses 1975-2000)

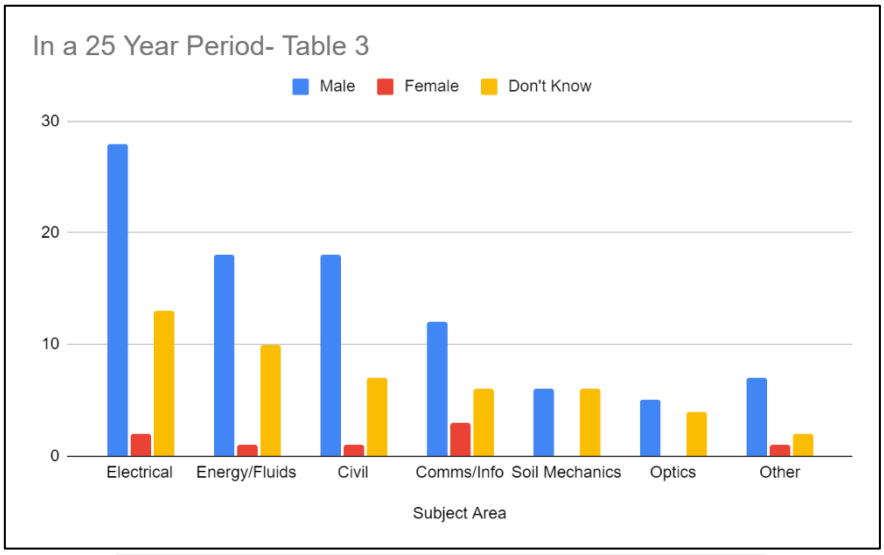


Fig 6: Distribution of Sex of Thesis Submission from Table 3 in the 25-year Period

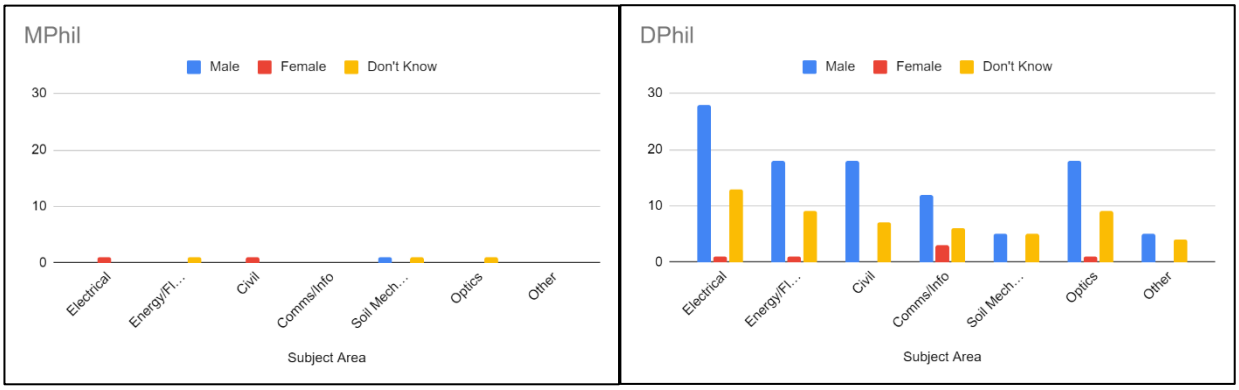


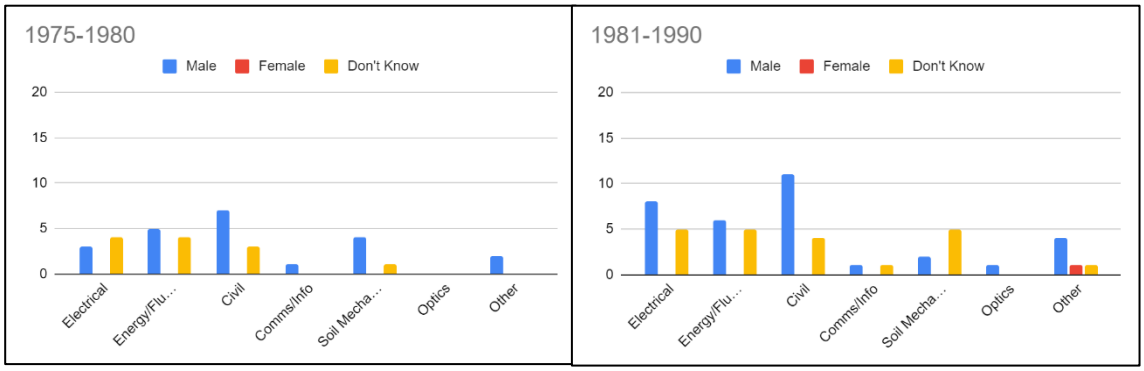
Fig 7: Distribution of Sex of Thesis Type from Table 3

Table 3 had 150 entries overall- 94 Males, 8 Females and 48 Unknown Sex across the 25-year period. This means that out of the 150 entries, only 5.33% were known females (and out of the total of known males and females, 7.84% were known females). The overall three most popular types of engineering for research (for both sexes combined) were Electrical (with 43 theses submitted- one MSc thesis and 42 DPhil theses), Energy/Fluids (with 29 theses submitted- one MSc thesis and 28 DPhil theses) and Civil (with 26 theses submitted- one MSc thesis and 25 DPhil theses).

Putting a disclaimer on the following analysis, the fact that almost a third of the entries cannot have a sex associated with them can dramatically change the outcome of the analysis. Spoiler warning, the proportion of known females submitting thesis in all the subject areas is definitely lower than that of Table 1. However, I predict that if we did find out the sex for those unknown entries, this difference in proportions would actually decrease (and by a significant amount). This reason I am raising this is because of the ways the names were presented to me during my data collection. Most of the names were initialled (instead of giving the full name) and also as the theses themselves were not made available, I did not have much to go off to find sex. This could mean nothing, and was just the way ProQuest formatted most names. However, there could be the argument that the reason for listing initials, rather than giving the first names, would be to give the author a level of anonymity in order to prevent gender bias from other scientists when crediting their work.

Nevertheless, it seems that the most popular research subject for women was Comms/Info, not only in the context of that grouping having the highest amount of known females choosing it (3 out of the 8 known females), but also having by far the highest proportion of female submissions within itself (between 14%-42% of the submissions were done by females- the big range is due to the 6 entries where the sex could not be deciphered). Also it was the only subject grouping (apart from the ‘Other’ group) where all submissions were for DPhils.

Again separating the theses into decades, we can see that there is a sharp incline of theses submitted by known females between 1990-2000. In fact, there was only one thesis before this decade from a known female, submitted in 1988, and was the only entry for Biomed.



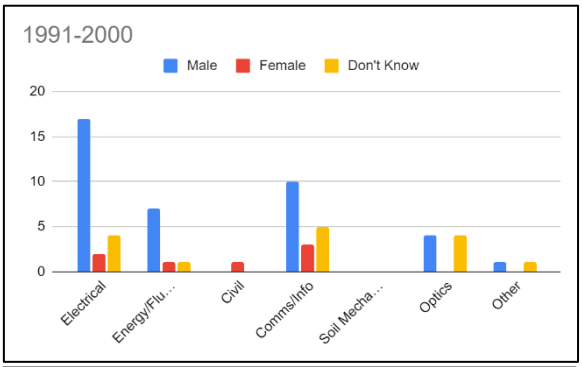


Fig 7:Distribution of Sex of Thesis Submission from Table 3 per Decade

Comparison between Tables

Doing the internal comparison (comparing Late 20th Century Oxford with Present Day Oxford) we can see that there has been a significant improvement within Oxford over the 17-year gap between tables. More women submitted theses in a time period that is a 5th of the size and in a smaller sample size than late 20th Century Oxford. Due to this, we can definitely see a shift in research domains. Research in Biomed/Biomech significantly increased in general popularity whilst other subjects (such as Soil Mechanics) which had major popularity within the Late 20th Century (particularly with men) decreased dramatically. To note, however, that there are also external factors that significantly contribute to this- such as funding distribution within the department and general societal needs at the time.

Doing the external comparison (comparing Late 20th Century Oxford with Late 20th Century KCL), taking into account the large uncertainties within Table 3, mentioned above, proportion of females submitting theses are roughly the same. The only significant difference between the two universities is the area of subject interest for research with Late 20th Century Oxford putting more focus on the Materials and the Soil Mechanics research groups while Late 20th Century KCL had a strong research team within the electrical domain.

Overall, it seemed that the most consistently popular subjects across the three tables for females to take were Biomed/Biomech and Electronics/Information (combining related groups together). These subjects consistently took some of the highest spots when comparing the most popular subject choices for known females. Even for Table 3, when there was only

one entry for Biomed out of 150, the thesis submission was done by a female. To contextualise these subjects, particularly within the time period of the late 20th century, these subject areas (especially Biomed) were quite new to the engineering research scene, particularly compared to other subjects such as civil or soil mechanics.

If I had more time and resources, I would definitely increase the sample size of each table. This could help with creating a more accurate analysis as there is more data to work off, creating more accurate percentages of known females. Also, hopefully it could mean that the proportion of unknowns in the data would decrease. I would have also done a fuller comparison between Oxford and the rest of the UK in the 1975-2000 time period. I understand right now, comparing Oxford with only one other university does not give the best representation for the intended analysis, but if I were to extend the project further, extending the range of universities in comparison can give a more accurate representation of Oxford compared to Britain.

Discussion

Linking together all the archival research, it is clear to see that within the time period of 1975-2000 there was a clear bias within the curriculum towards men. Although Oxford Engineering did not explicitly act to deter women from pursuing HE in the subject, it is clear that these implicit biases came from the way the curriculum was structured and assessed, assumptions about the knowledge that students will have when arriving and emphasis (and probably funding) on the research of certain subjects. I state the latter point as within late 20th century Oxford there was a significant number of theses on Materials and Soil Mechanics (almost half the entries were of these research subjects alone- 73 total) which are very traditional subjects of research, yet only counted for 4 entries being known females combined. Conversely, Biomed/Biomech and Electronics/Information seemed to be the most popular subjects for female study, suggesting that women seem to be more likely to pursue research (and careers) in newer domains in engineering, rather than taking more traditional subjects. However, emphasising departmental research in areas of less interest to women, in general terms, could have made women less likely to study at Oxford.

Another flaw with the programme at the time, which remains relevant in today's curriculum, is how much the course relies on theory-based teaching and how it is so isolated to current society. The engineering industry is very interlinked with society. Projects have close ties with economic and political states of communities as well as most of them starting as an idea to benefit society in some way- and hence, to understand the way a current society functions is invaluable to creating a successful engineering career. As it stands, there is only

one module in the entire 4-year curriculum that specifically deals with engineering in society- B2: Engineering in Society module taught in 3rd Year. On one hand, it is a compulsory module so every engineer that graduates from Oxford (even those who graduate with a BEng) has had some learning in that area. However, this is nowhere near a satisfactory amount in teaching in the subject area for students to truly appreciate the role society has within engineering- particularly as the course does not offer a year in industry and so students are less likely to learn the link first hand. How does this link with women in HE? Including more teaching on how engineering links with society, brings an external viewpoint to the subject. As mentioned before, generally, women are more likely to value success outside of engineering itself. Broadening the course from being almost solely technical and theoretical and adding some subjectiveness may in turn broaden the pool at which the course interests.

Research Today

Research is still being done today on trying to understand why women leave the engineering sector, if they even choose to pursue in that direction. Surprisingly, I found that research still offered similar reasons as 30 years ago. Research done by Kahn and Ginther in 2015 suggests that still today some women face 'chilly climates'.[35] Even though this is to a lesser extent, this was a phrase that I became very familiar with when reading research done within the 1980s and 1990s and it was disappointing to find it being used in a paper written 20-30 years later. It shows the reluctance of some institutions and the traditional and outdated values that they still uphold. This research also mentions how 'Family status is of key importance'. Relating to the point I made earlier on part-time graduate degrees, although in present times as societies attitudes have changed overtime, in this instant particularly revolving around women's roles within families, there is still a societal expectation that women are to provide childcare for their children over men and hence many women leave the workforce early or don't get the opportunity to pursue research. It has been proved that single women are less likely to leave the field early, meaning that still today there is a pressure for women to either choose family or work.

Even though it is against the law to provoke gender inequality, it still lurks within attitudes in certain professions. Salas-Morera, Ruiz-Bustos, Cejas-Molina, Olivares-Olmedilla, Garcia-Hernandez and Palomo-Romero state how 'the ratio of girls that are convinced that engineering is a male profession is still 48% compared to 34% of boys'.[36] When trying to figure out this mindset, the girls could not explain why. Again, this further

[35] Shulamit Kahn and Donna K. Ginther, "Are Recent Cohorts of Women with Engineering Bachelors Less Likely to Stay in Engineering?," *Frontiers in Psychology* 6, no. 1144 (August 19, 2015), 2, https://doi.org/10.3389/fpsyg.2015.01144.

[36] Lorenzo Salas-Morera et al., "Understanding Why Women Don't Choose Engineering Degrees," *International Journal of Technology and Design Education* 31, no. 2 (October 22, 2019): 335, https://doi.org/10.1007/s10798-019-09550-4.

implies how integrated traditional and sexist views are integrated into society. ‘a group of university teachers designed a set of activities in order to eliminate misconception about gender in engineering degrees’- the importance of education within trying to undo these sexist viewpoints in society cannot be overstated. Educators have a responsibility to destroy both explicit and implicit discrimination (in our case sexism) that society has taught students in believing.

This includes trying to avoid being biased in the classroom. This statement appears easy on the face of it; however, some women continue to feel isolated in HE Engineering classrooms when teachers try to relate through examples and analogies. MacLean, 2017, states that when ‘talking about a centrifugal force used for the example of motorcycles going round a circular track instead of a more obvious example of a washing machine spinning clothes’.[37] To be clear, interest in motorcycles is definitely not exclusive to men, however, using more ‘masculine’ analogies to relate the concepts of physics to real life, presents engineering in a specific light- one that women are less likely to relate to.

Active Progression

To touch further on my idea above about expanding the Engineering in Society module, aspects of this subject should be taught earlier on in the degree. Not only will this mean that society’s influence on engineering will be taught at a satisfactory depth by the end of someone’s degree, but it gets students thinking from the outset how theoretical principles would be applied in the present.

When learning so much theory throughout the year, it can sometimes be difficult to see how these principles relate to real-life applications. As shown above, a lot of research has been done comparing sex to teaching styles, with a conclusion that in general, women are more likely to learn better through practical experience. It may be an effective way to increase the significance of practical work, especially during the first two years of the course (where everything is compulsory), to not only boost female applicants but also keep the retention rate of women within engineering.

Going back to Mills and Ayre, they mention how a curriculum is made using the following steps in order: ‘Assumptions made about the perspectives, experiences, values, and background of the students, The aims and objectives of the program or course, The content, The teaching and learning methods, The resources used, How the students are assessed, and

[37] Lisa M. MacLean, *Cracking the Code: How to Get Women and Minorities into STEM Disciplines and Why We Must*, ed. John K. Estell and Kenneth J. Reid, 1st ed. (2017; repr., New York: Momentum Press, 2017), 42, https://ebookcentral.proquest.com/lib/oxford/reader.action?docID=4791046.

The general learning environment'.[38] They suggested that in order to make an inclusive curriculum, one should be made by completing the steps in reverse order. I agree with this. In order to create an engineering curriculum that truly does not have any implicit biases link in (or at least a curriculum where these biases can be exploited and discussed to improve), one needs to look at the present society around them and properly observe how prospective students learn, are taught, what they are taught and their educational environments overall. Not make assumptions by looking at small samples that do not reflect the population properly. In my opinion, this is where research in this area should shift focus to. From reading alone, I have been able to paint a detailed picture of what it is like to be a female engineer both in the time of 1975-2000 and in the present day. It is time now to start researching ways in which a curriculum can be more inclusive and how it would be received in engineering departments.

Further extensions of this project could expand outside of Oxford and university education to look at gender biases within technical subjects and their curriculums earlier within the education system (e.g. A Levels and GCSEs). There is currently a national movement to push girls to enroll in A Level Physics, as it is by far the least popular science for them to take, as well as Maths but to a lesser extent. This again ties back to sexist views that Western Society still holds and teaches younger children that men are more likely to go into science whilst women are more likely to go down the arts route.

Particularly between 1975-2000, there was a lot of research as there was a social change to push more women into technical subjects including engineering. In 1987, EITB (Engineering Industry Training Board) produced a report on 'Trends in employment and training'.[39] Within its education section, there are two main things to note. The first obviously being the disparity between sex within A Level Maths (in 1985, 26000 entries for females and 61000 entries for males) and Physics (in 1985, 11000 entries for females and 41000 entries for males) but also the fact that the average pass rate for each sex has practically no difference between each other. This emphasises that the fact that less girls choose technical subjects is mainly an attitudinal issue. To combat this, however, the EITB published a set of initiatives in 1987 to help girls in lower education (especially those from access backgrounds) to pursue further education and training in technical subjects.[40] It was a set of programmes

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[38] Julie Mills and Mary Ayre, "Implementing an Inclusive Curriculum for Women in Engineering Education," *Journal of Professional Issues in Engineering Education and Practice* 129, no. 4 (October 2003): 206-07, https://doi.org/10.1061/(asce)1052-3928(2003)129:4(203).
Engineering Education and Practice 129, no. 4 (October 2003): 206-207, https://doi.org/10.1061/(asce)1052-3928(2003)129:4(203).

[39] Sharon McGuire, C.J Laidlaw, and Engineering Industry Training Board, *Women in Engineering: Trends in Employment and Training* (Watford: Engineering Industry Training Board, 1987), 29–30, 57–59.

[40] Sue Peacock, Catherine Eaton, and Engineering Industry Training Board, *Women in Engineering: EITB Initiatives* ([Watford?]: Engineering Industry Training Board, 1987), 3–26.

and scholarship opportunities to help girls destroy sexist misconceptions whilst also getting hands-on experience of what it would be like to work in a technical field.

Taking a deeper look at the A Level (and potentially GCSE) Physics and Maths curriculums and general teaching of the subjects to understand why girls are often deterred from taking them at A Level could shed light onto whether it is purely just an interests reason, or whether attitudinal barriers play a part in this as well.

Conclusion

In conclusion, I have looked at how the HE engineering curriculum, particularly at Oxford, is implicitly laced with attitudinal (and some physical) barriers against women to pursue engineering either within the workplace or within research. I looked at how this issue was present at the turn of social change in the late 20th century and compared it to today's curriculum, seeing how much the department has progressed over the past 22 years. Even though the curriculum made at the Engineering Science Department here at Oxford was not intended to include gender bias, due to a general nature of how a curriculum is made, the course is implicitly better suited for a cis-white man. I have also suggested ways in which the course could be improved looking mainly at changes to the course content and structure, as well the emphasis of more practical teaching and assessment. One more thing I would like to note is that even though I have taken this opportunity to explain how the curriculum is flawed in terms of diversity and inclusion, I cannot finish this paper without acknowledging that the department has indeed made improvements and initiatives internally to help increase the percentage of the female cohort (which currently stands at around 27% for undergraduate offers made for female students).[8] This number is slowly but surely rising; however, it is still far from its intended equilibrium (whether the split of sex is intended to be 50/50 or not), hence why I think it is important to look at the curriculum internally to weed out the inherent sexist biases that may be present there.

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