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The Impact of Gender on Engineering Students' Group Work Experiences*

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Women remain significantly underrepresented in engineering education, a cultural milieu which is stereotypically seen as a masculine domain. Laboratory studies and some questionnaire-based studies suggest being numerically under- or over-represented in student working groups may have an impact on the group work experiences of both female and male engineering students, however this has not previously been adequately explored in realistic engineering education team work settings. Using a quasi-experimental survey design with 217 participants, we document a number of micro-discriminations with respect to women in student work teams in engineering education. Both male and female students seem primed to anticipate potential difficulties arising for female students to a greater extent than for male students, even among high performing students. This suggests a cultural, implicit bias. As such, student group work in engineering programmes may need to be accompanied by teaching and learning strategies which seek to actively question such stereotypes and implicit biases.

Keywords: engineering education; gender; group work; tokenism; stereotype threat

1. Introduction

The prevalence and experience of women in engineering and engineering education remains an issue of concern internationally. It has been noted [1] that, in the US, while federal policy has aimed at increasing recruitment of women (and other minorities) into engineering since the 1970s, progress has been slow. While the proportion of women enrolled in higher education programmes more generally has grown since the 1980s, "minimal progress has been made in recruiting and retaining students, and especially women and minorities, into engineering programs" [1, p. 314]. By the end of the first decade in the 21st century, only 1.3 per cent of bachelor's degrees earned by women were in engineering, as compared to 8.2 per cent of men's bachelor's degrees [1, p. 317]. Similar figures could be cited for other western countries, including the UK, where only 15 per cent of engineering and technology undergraduates were women [2], as well as countries like Lithuania, Serbia, Austria, Spain and France [3].

Part of learning to be an engineer is learning to work as part of professional teams. This is acknowledged by a number of accreditation bodies, which have made communication skills and group work experiences required elements in the curriculum [4, 5]. Team projects are, therefore, common in engineering education [6]. The low proportion of female engineering education students, however, means that it is likely that female students will often be in a minority within such teams. Over the last thirty years a significant body of research has developed about the impact of being a 'token' female in a male-dominated group [e.g., 7–9]. This research predicts that when women are in male-dominated groups they will show, on average, poorer performance and reduced confidence in their own capacity as compared to women in more gender-balanced teams. Such effects have not, however, been well-documented in engineering education, especially with students who have already completed first-year or introductory courses. Nor have other interactional effects (female students in female-dominated groups, male students in female-dominated groups, and male students in male-dominated groups) been adequately documented in engineering education settings.

In this paper we will (a) briefly describe the literature on gender stereotypes in engineering, and (b) describe how different research methodologies have been used to explore the effect of token representation in team work settings. We then describe the quasi-experimental survey research design which we used to address gaps in this literature, and our findings. While we do find evidence of micro-discriminations with respect to female students, we do not find evidence of a 'token' effect *per se*. This has implications for how student work groups should be organised.

2. Literature review

2.1 Gender and roles in engineering teams

Engineering education is not simply numerically male dominated, it is also culturally associated with masculinity. One review of evidence [10]

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found that engineers in general (and computer engineers in particular) are stereotyped as socially awkward, 'geeks', infatuated with technology, dissociated from community and from caring roles, and as being males, with glasses, and pale skin. They report that in the US, 84% of high school students mentioned at least one of these traits when asked to describe a computer scientist [10, p. 3]. They report that, unlike males, girls and women are more likely to see themselves as dissimilar from those in the field and as having a lower sense of fit with the field. As a result, female students are confronted with what is often perceived as an incompatibility between their gender identity and their discipline of study. Female students in sciences, mathematics and engineering can be seen as on the margins of their disciplinary practice and as consequently having "fragile identities" [11], only acceptable so long as they are not 'girly girls' [3], and as such, experiencing a 'chilly climate' [1]. Barnard et al. [3] interviewed female engineering students who describe examples of explicit discrimination such as being told by a lecturer that women don't belong in engineering. Even when such gender identification is not made explicit it may still have an impact upon people's actions. Work which has drawn on data on the Implicit Association Test [12] which had, at that time, been administered over 500,000 times across 34 different countries has shown that over 70% of respondents showed an implicit association between masculinity and sciences, and that across countries this bias was associated with differential performance rates in mathematics [see also 13, 14]. Implicit bias effects have also been found in science faculty members, where both female faculty and their male counterparts have been found to be less likely to offer mentoring to female students when compared to otherwise equivalent male students [15].

These biases and stereotypes have also been found to be evident in looking at the roles which males and females are assigned or take on in group work settings. Studies from outside engineering education have found, for example, that men in general talk more and more assertively in small group settings [16, 17]. Although the association is, in general, quite weak, it does emerge more strongly among undergraduate students and when working with unfamiliar people, both of which are characteristics of undergraduate engineering teams [18]. In first-year engineering project groups, observational research [18] has found that male students spoke for longer during presentations, answered more questions and were more likely to present technical content than were female students. Data from focus group and interview research suggests women were less likely to take on technical roles within project groups [18, 19] and were more likely to be assigned supporting or 'secretarial' roles. Research on speech dynamics within small groups found engineering students tended to be harsher in their judgement of female-typical speech acts when compared to non-engineering students, and that engineering student culture favoured masculine interactional norms [20].

Although valuable, a number of the studies cited here deal either with non-engineering education domains, or draw only on data from introductory or first-year students. However, women who persist beyond first year in engineering programmes are typically higher performing than their male counterparts and have a high sense of self-efficacy when compared to women who do not persist beyond first year [21]. It would be useful therefore to know whether the gendered patterns of experience found in such studies remain evident among students who have persisted to later stages of an engineering degree programme where female students have already demonstrated resilience against gender stereotypes and discriminatory attitudes and behaviour.

2.2 Minority status and 'tokenism' in engineering education

The climactic and cultural issues addressed so far exist irrespective of the numerical balance within engineering programmes and student groups. Additional issues arise from the numerical dominance of male students which means by definition that female students are more likely to be 'token' females in majority male groups. The concept of 'tokenism' was introduced by Kanter some thirty years ago [7, 22]. Kanter argued that when women were in a significant numerical minority in groups, they felt additional pressures to perform well as representatives of their group, they felt isolated from social supports and they felt their differences from male counterparts was heightened. Kanter's work has been applied more widely, re-examined and refined repeatedly over the last thirty years in a number of different ways.

Laboratory studies of tokenism in group interaction have found that women participate less than their equal share in group discussions when they are in a minority but at equal rates when they are in a large majority, whereas men do not appear to be disadvantaged in terms of talk time by their proportion in a group [17]. Such laboratory experiments have also found that women's performance on tasks is generally diminished when they are the sole woman in a male-dominated group, but that this effect was most evident in tasks which are stereotypically male [23, 24] or when minority status is compounded by the existence of explicit stereotypes

[9]. This negative impact of tokenism on women is most evident at highest levels of performance [25]. Laboratory experiments have also identified that tokenism has a negative impact on confidence of women but not of men [26] and that acting according to stereotypical roles when in a minority position is evident in both men and women, but that this is typically beneficial to men because masculine stereotypical roles include leadership [26, 27] but may be costly for men where tasks are defined so as to imply female advantage [24]. These findings are often explained in terms of the idea of 'stereotype threat' [27, 28] which proposes that when a person is in a situation in which a negative stereotype about their group exists, then the awareness of the stereotype impedes one's performance in line with the stereotype.

While these laboratory studies allow us to develop a more refined understanding of the social processes associated with being a sole or token male or female in a group, they are generally based on experiments run over short time periods and so can tell us little about how token status impacts upon decisions over a longer term [29, p. 442] and obviously cannot tell us much about the specific ways in which these processes will become evident in the real-world setting of engineering education [see 21, p.54].

For this, cross-sectional (survey) research or qualitative data is valuable. One survey of female engineering students [30] has identified that their sense of inclusion in their programme reduced over time, while another, based on a large sample of some 4,000 responses [29], identified that the extent to which student's felt that they were seen as a representative of 'people like them' had an impact on their long term persistence in engineering education. Males working in settings in which they were numerically dominant have been found to tend to see women as more homogeneous and, as a corollary, as having lower status, when compared to men in more mixed workplace settings [31], while similar findings have been reported for university students, including engineering students [8]. A study of German engineering students [32] found few differences between male and female students in terms of self-efficacy and overall satisfaction, but did find that working in gender mixed teams was regarded as more important for female students than for male students.

These survey studies can tell us something about women's (and men's) experiences in real-world token-type situations, and sometimes can tell us about experiences in engineering or engineering education but typically are not focused on students' experiences in group work settings. Furthermore, such approaches are often insufficiently sociological, in that they tend not to explore interactions and relations within gender groups as well as across such groups [33, 34]. One way of overcoming this difficulty is through rich and detailed qualitative descriptions of gender and engineering identity [see, for example, 33–35], including studies of teamwork experiences. While incredibly valuable for theory generation, however, if we are to have an idea about the incidence of particular phenomenon in engineering education, we will also need methodologies that allow us to work with relatively large numbers of research participants.

Two important features should be noted about many of the studies listed above. Firstly, the effects identified are often not very evident. Gender differences in team talk were typically weak [17], while some studies [31] did not find expected differences in visibility and performance pressures associated with token situations and others [32] did not find expected gender differences in self-efficacy or general satisfaction. In this context, it is valuable to note that, rather than major and obvious discrimination, women in engineering programmes are often subject to a pattern of micro-discriminations which individually may appear to be insignificant but which cumulatively add up to contribute to women's continued exclusion from the field [36]. Research evidence suggests micro-inequalities in social integration, interests and self-efficacy deserve particular attention [36, p. 681], but that the relatively minor nature of each individual form of discrimination may well make them hard to identify. A second point worthy of note is the existence of studies which try to bridge the internal validity of experimental design with the external validity of field-based studies. A quasi-experimental design has been used in a number of studies [15, 20, 32] which involved either (a) identifying gender-imbalanced settings and surveying people in those contexts in order to mimic the effects of a control and experimental group while in a real-world setting or (b) using multiple versions of research materials which allows researchers to mimic a control and experimental group. This quasi-experimental survey methodology appears to be a promising one which can give a degree of internal validity while ensuring the findings remain relevant for the wider world.

In summary, the research literature highlights that the experience of women and men in group work settings in engineering education is likely to be impacted at two different levels. At a general level, stereotypes and implicit biases may lead to differences in the tasks assigned to or adopted by male and female students. Whether or not these patterns continue beyond the early stages of engineering education and with resilient and persistent students is, however, and open question. At a deeper level, the gender ratios among the student population may also lead to token or stereotype threat effects. Although these have been found in experimental settings and can be hinted at by field-based research, the experience of being either a woman or a man in an engineering team work setting who is in a situation of either numerical under- or over-representation has not previously been adequately explored. A quasi-experimental survey design appears to be an interesting methodological approach which could allow for a degree of internal and external reliability.

This paper addresses these gaps in the existing literature as follows:

- We use a quasi-experimental survey design which allows us to combine both internal validity with external validity;
- The study is based on a 2 × 2 design (male/female × numerical minority/numerical majority setting) which allows us to explore both inter- and intra-gender effects for both female and male students;
- We administered this survey to advanced (3rd and 4th year) engineering students to identify where such effects are evident beyond the initial stages of a degree programme and with students who have been persistent in engineering education.

3. Methods

3.1 Participants

A survey was administered to 217 3rd year Bachelor and 1st year master students of a large mainland European engineering school in the spring of 2016. All of the students will have been through either a highly selective exam at the end of their first year of studies or through a very competitive entry process for the master programme. As such, all participants can be expected to be highly performing in science and engineering courses and to be resilient.

Most of the respondents (88.9 per cent) were in the first year of their master programme, with the remaining 11.1 per cent being currently in 3rd year. Of the students at master year level, 76 (35 per cent of the total responses) had completed their first three years (i.e., a Bachelor's degree) at other universities. The students were drawn from all faculties on the campus (including natural sciences, life sciences, engineering, architecture and computer and communication sciences), although computer science students were slightly over-represented compared to other groups.

In order to maximise the response rate, questionnaires were administered to whole classes rather than being sent to randomly sampled individuals. Because the representation of female students varies significantly from class to class, randomly choosing classes to survey ran the risk of having female students significantly under-represented. A purposeful sampling strategy was therefore used, where classes were selected in order to ensure a broadly proportional representation of female students in the sample. Professors were asked permission to distribute questionnaires to their class. The gender breakdown of the students who responded to the questionnaire was 75.6 per cent male (164 of the respondents) and 24.4 per cent female (53 of the respondents). While female students are slightly underrepresented among the respondents (female students make up 29 per cent of the students in the school as a whole), the female students were distributed across the different faculties at levels close to their frequency in the population. Since the sampling method is non-random, care should be taken in statistical generalization from this sample to the wider population. Nonetheless the more or less representative nature of the sample gives reason to think that findings may be generalizable.

3.2 Materials

A questionnaire on student group work experiences was developed. The questionnaire contained 47 questions addressing the following areas: self-efficacy beliefs about teamwork (15 questions), prior experiences in teamwork (10 questions), scenario response questions (10 questions) and demographic data (10 questions). All except the demographic questions were Likert scale questions with 5 responses (from 'strongly disagree' to 'strongly agree').

In line with the quasi-experimental method described in section 2.2, two versions of the questionnaire were used. In version A, the students were asked to imagine themselves in a group with three students named Mary, Sarah and Allison, and to indicate how likely they were to respond in particular ways to various scenarios. Version B was identical except that they were asked to imagine themselves in a group with students named Mike, Samuel and Jack. This allowed us to collect data on student's perception of the behaviour and beliefs in group work settings, while controlling for the gender of the other team members. As such, this methodology allowed us to collect data in realistic settings (maintaining external validity) while controlling for all facts other than gender make-up of the group (thereby maintaining internal validity).

The context for the scenarios was described as follows:

> You are working on a group project with a team of 4 [three other team members' names inserted here]. . . The project is fairly large and accounts for a big part of your

grade. It includes many technical aspects, a report and a presentation. The project has many different moving parts that all need to come together at the end. It is very open ended and will surely require some kind of game plan and strategizing at the beginning to get things going.

Examples of specific scenarios that students were asked to respond to are found in Table 2(a) and (b).

In order to maximise the readability and therefore reliability of responses, students were centrally involved in drafting the questionnaire (as the response items are not amalgamated to construct broader construct scales, it is not appropriate to report on statistical reliability [e.g., alpha scores] or factorial validity of scales).

Design: The study was based on a quasi-experimental design within the survey method, similar to that used by Moss-Racusin et al. in their landmark study on gender biases in science faculty [15]. Two independent variables were considered: gender of respondent, and gender make-up of the group work scenario. The design of the survey and its administration allowed four situations to be compared: (a) female students in male-dominated groups, (b) female students in female-only groups, (c) male students in male-only groups and (d) male students in female-dominated groups. Dependent variables included their prior experience in undertaking technical, managerial and non-technical aspects of team projects and their responses to various scenarios presented. While Likert scales are ordinal, where there is adequate sample size, ordinal data can be treated as if it were continuous and can be analysed using (more powerful) parametric tests [37, 38]. Since, our sample size is large enough, we can use parametric tests with our data.

Procedure: In each class, Questionnaire A was administered to one half of the room and Questionnaire B to the other. Questionnaire A (in which the respondent imagines they are working with Mary, Sarah and Alison) was administered to 114 respondents (30 female and 84 male) and Questionnaire B (Mike, Samuel, Jack) was administered to 103 respondents (23 female and 80 male). The questionnaires looked identical and gender was not explicitly mentioned as an issue anywhere in the questionnaire, and so students did not know they were responding to different questionnaires or that gender was a key variable under investigation.

The study was conducted under a protocol approved by the Ecole polytechnique fédérale de Lausanne (EPFL) Human Research Ethics Committee (010_09/12/2014).

4. Results

There were some similarities and differences between male and female students in their prior experience of group work tasks they had previously undertaken. These can be seen in Table 1.

In areas such as making slides for presentations and organising meetings, there is little difference between the male and female students. However, there are very notable differences in their experiences in writing reports and in completing technical aspects of a project, with female students more likely to typically work on report writing and male students more likely to report that they typically work on tasks like coding, mathematical proofs, and statistical analysis. In educational settings, effect sizes of $d = 0.4$ or higher are regarded as being quite notable [39]. The effect of gender on whether or not a student engages in technical aspects of group work is, therefore, strong, while the effect on the likelihood that they typically write reports is moderate to strong. It is important to note that, despite the strength of these effects, most students do report that they regularly work on both technical and write-up aspects of projects: 75.5 per cent of female students report that they 'often' or 'always' work on technical aspects of reports (compared to 90.3 per cent for male stu-

Table 1. Gender differences in activities typically undertakes in student group work projects by male and female engineering students

Activity type	Gender	Mean	Standard Deviation	p-value for 2 sample t-test (df=215)	Cohen's d effect size
Making PowerPoint presentations	Female	2.15	1.17	0.265	0.11
	Male	1.93	2.54		
Writing reports	Female	3.02	0.93	0.023*	0.38
	Male	2.63	1.12		
Technical work (coding, mathematical proofs, statistical analysis)	Female	2.72	1.10	<0.001***	0.52
	Male	3.23	0.83		
Organizing meetings	Female	2.13	1.46	0.082	0.02
	Male	2.16	1.37		

Note: Question asked "What are the tasks of a project you typically end up working on?" Students were presented with each task type and could respond ranging from 0 ('never') to 4 ('always'). 53 responses are from Female students, 164 are from male students. * Indicates significant at 0.05 level; ** Indicates significant at 0.01 level; *** Indicates significant at 0.001 level.

Table 2(a). Response of female students to groupwork scenarios in male-dominated and female-only groups

	Mary, Sarah, Allison Group		Mike, Samuel, Jack Group		p-value for 2 sample t-test (df=51)
	Mean	**St Dev**	**Mean**	**St Dev**	
You'll let other team members take the initiative in getting the project moving at first.	1.67	1.18	1.57	1.12	0.753
You prefer knowing about every part of the project to be sure everything is just right and often find yourself as the one trying to make sure everything fits together.	3.20	0.93	2.65	0.98	0.042*
B is starting to fall behind on his part of the project. You will pick up the slack and just do his/her part instead of him/her.	1.70	1.18	1.48	1.12	0.482
A is assigned to handling the technical aspects of the project. You are concerned that he/she won't be able to handle her/his assigned role.	1.70	1.12	1.65	1.19	0.881
You are confident that your opinions/suggestions about the project will be valued as much as anyone else's in the group.	3.07	0.87	2.96	0.98	0.666
A is assigned to handling the non-technical aspects (e.g., organization or writing reports) of the project. You are concerned that s/he won't be able to handle his/her role.	1.53	1.11	1.35	1.15	0.555
C often asks you about how your part of the project is progressing. You are likely to think that s/he doesn't trust you and is monitoring you too closely.	1.23	1.23	1.30	0.88	0.820

Note: Students were presented the scenario and could respond ranging from 0 ('strongly disagree') to 4 ('strongly agree'). 53 responses are from Female students. * Indicates significant at 0.05 level; ** Indicates significant at 0.01 level; *** Indicates significant at 0.001 level.

Table 2(b). Response of male students to groupwork scenarios in male-dominated and female-only groups

	Mary, Sarah, Allison Group		Mike, Samuel, Jack Group		p-value for 2 sample t-test (df=162)
	Mean	**St Dev**	**Mean**	**St Dev**	
You'll let other team members take the initiative in getting the project moving at first.	1.65	1.08	1.55	1.08	0.552
You prefer knowing about every part of the project to be sure everything is just right and often find yourself as the one trying to make sure everything fits together.	2.96	1.06	2.94	1.01	0.869
B is starting to fall behind on his part of the project. You will pick up the slack and just do his/her part instead of him/her.	1.88	1.15	1.41	1.13	0.009**
A is assigned to handling the technical aspects of the project. You are concerned that he/she won't be able to handle her/his assigned role.	1.59	1.11	1.95	1.18	0.046*
You are confident that your opinions/suggestions about the project will be valued as much as anyone else's in the group.	3.46	0.70	3.29	0.99	0.197
A is assigned to handling the non-technical aspects (e.g., organization or writing reports) of the project. You are concerned that s/he won't be able to handle his/her role.	1.40	1.08	1.49	1.03	0.588
C often asks you about how your part of the project is progressing. You are likely to think that s/he doesn't trust you and is monitoring you too closely.	1.74	1.18	1.50	1.08	0.181

Note: Students were presented the scenario and could respond ranging from 0 ('strongly disagree') to 4 ('strongly agree'). 164 responses are from male students. * Indicates significant at 0.05 level; ** Indicates significant at 0.01 level; *** Indicates significant at 0.001 level.

dents) and 71.3 per cent of male students report that they 'often' or 'always' work on report writing (as compared to 84.9 per cent of female students). It is also notable that in other areas of team work no significant differences are evident. Hence, although there is a moderate to strong gender effect in these two measures, it may not be immediately evident to the male and female students themselves, who will be aware that they work on both aspect on a regular basis.

The scenarios presented to respondents allowed us to compare how they think they would react in male-dominated and female-dominated groups. This data is presented in Table 2(a) and 2(b). Again, we can see that by and large, there are few differences between how students report they would react in male-dominated and female-dominated groups. In a small number of areas, however, students do report that they would react differently.

As Table 2(a) shows, female students in female-only groups are more likely than those in male-dominated groups to report that they "prefer knowing about every part of the project to be sure everything is just right and often find yourself as the one trying to make sure everything fits together". As Table 2(b) shows, perhaps unexpectedly, male students are more likely to report that they would have concerns about a fellow student's ability to handle a technical role when that fellow student is male. More in line with expectations, they also report that they are more likely to "pick up the slack and just do his/her part [of the project] instead of him/her" if their fellow student is female. Outside of these three areas, however, how students report they would behave does not differ a lot depending on the gender make-up of the group.

There is one other notable and significant difference which can be seen by comparing the data in Tables 2(a) and (b). While the data does not suggest that male and female students' confidence that their opinions/suggestions about the project will be valued differs depending on the gender make-up of the group, it does seem to vary depending on the gender of the respondent themselves: male students are more likely than female students to report confidence in their own opinions and suggestions being valued (mean of 3.38 as compared to 3.02 for female students, $t = -2.633$, $df = 0.214$, $p < 0.01$).

5. Discussion

Our starting point in this paper was to note that the experience of men and women in teamwork in engineering education may be influenced by cultural stereotypes and implicit assumptions about gender and engineering, or by a token effect, or both, or—theoretically at least—by neither. Our data allows us to explore which of these factors appear most evident.

Prior data from introductory or first-year course had previously identified that male students tended to be dominant in technical roles in student groupwork, with female students describing themselves as being assigned more 'secretarial' roles [18, 19]. We noted that there was a need for data to show whether these patterns persisted among more advanced students, since previous research had suggested that women who persist in engineering are often higher performing than their male counterparts and have a high sense of self-efficacy than female students who do not persist [21]. Our data suggests that these patterns do in fact continue; we found that among 3rd year Bachelor and 1st year master students, females were significantly more likely to work on report writing while males were significantly more likely to work on technical tasks in student teams.

Although these effects were moderate to strong (with notable Cohen's d scores, for example), it is important to recognise that, despite the strength of these effects, both female and male students report that they regularly work on both technical and write-up aspects of projects. This means that, while these differences are detectable using quantitative social research they may not be immediately evident to the students themselves (or their teachers) who would instead see that most male and female students normally work on both aspects of group projects. This may help to explain why relatively few female students and even fewer male students report seeing discrimination in engineering education [32]. More generally, this data fits with the concept of 'micro-discriminations' [36]. Such micro-discriminations may well be cumulatively having important negative impacts on female students even if they are not immediately evident to the students themselves (and may not, therefore emerge in interview-based research or in questionnaires with a different design).

A second potential impact which we noted above were effects arising from the experience of being a 'token' female in male-dominated work groups. Indeed, the methodology used allowed us to go further and do something which, as Hewstone et al. note, is "rarely done in this literature" [31, p.524], that, is compare men and women in both majority and minority settings. While much of the experimental literature would have led us to expect an effect from being a 'token' women in a male-dominated work group, we found few differences in the expected behaviour for female students in female- and male-dominated groups: no differences between male- and female-dominated groups were found in female students' confidence that their opinions would be taken on board or in the likelihood that they would take the initiative in the project, for example. Indeed, solitary male students in female-dominated groups actually report fewer concerns about their teammates' technical competence than males in male-only groups.

Where there are differences in male and female students' reports of their expected behaviour in project groups, these seem to be more linked to stereotypes and implicit biases in general rather than to token effects in particular. For example, female students reported that they were more likely to "prefer knowing about every part of the project to be sure everything is just right. . ." in the case of female-only groups when compared to male-dominated groups. Likewise male students indicated that they were more likely to "pick up the slack and just do his/her part instead of him/her" when in female-dominated groups. These results suggest that rather than a 'token' effect for lone women in male-dominated groups, within student teams, both male and female students seem primed to anticipate potential difficulties arising for female students to a greater extent than for male students. There is evidence [15] that both male and female professors in scientific disciplines demonstrated similar bias against female students—our data suggests a similar pattern is also evident in how advanced engineering students interact with their peers. It is, therefore, perhaps not surprising then that male students were also more likely than female students to report confidence in their own "opinions and suggestions being valued" in student teams.

Overall then, this paper makes a number of contributions to the literature. While 'token' effects have been found in laboratory studies, our quasi-experimental survey design allows us greater external validity than such studies because our data is collected in the field with more 'life-like' settings. In our data we did not find 'token' effects, however we did find that gendered stereotypes appears to have an impact on attitudes and experiences of male and female students even when they are at a more advanced stage of their studies. While previous studies have found such effects in first-year or introductory courses, our data suggests such effects persist even when both female and male students have repeatedly demonstrated their competence and resilience. Our data also has implications for educational practice. For example, Cox formed a single all-women project group, due to the gender makeup of his software engineering course and his intention to decrease gendered roles within the design teams [40]. Because we cannot rule out a 'token' effect on women in engineering student groups (perhaps particularly in the initial stages of their education), we are not critical of the idea of single-sex groups for female students, *per se*. However our data suggests that female-only teams may not be enough to have the positive impact desired, since implicit biases continue to be evident in the expectations and behaviour of both women and men. Instead, broader teaching and learning strategies which seek to actively question such stereotypes and implicit biases [see, for example, 41] may be more appropriate. Doing this, may require overcoming some resistance from engineering faculty to dealing with gender (and other diversity) issues within advanced engineering courses that involve student team work [42].

It is important to note some of the limitations of our study. First, although our study is designed to approximate real-world team work settings, we did not actually observe real work teams. Rather our data collected self-reports of how students thought they would behave under particular circumstances. Secondly, our sample was collected in a non-random way. Although this methodology was necessary because of the low incidence of women in the wider population, it does mean that, as we noted above, we would be cautious about being too categorical in drawing generalisations from our sample. Thirdly, we were attempting to study what we had reason to believe were relatively small differences between male and female students. Obviously a larger sample size would make it easier for statistical significance of such small differences to be evident. In mitigation of those limitations, however, we would note that our sample is comparable in size to those used in many other published studies in the same field, and our data comes from a setting in which it is even more difficult to get large and representative samples since our focus meant we did not look at large first year or introductory courses. While a larger sample would be preferable, we feel our sample size and methodology is reasonable given these real-world constraints.

6. Conclusions

The cultural and organisation factors that limit women's entry into science and engineering, and which impact upon their persistence beyond introductory or first-year courses have been well documented. Our data suggests that even those who show the ability, interest and resilience to stay in engineering programmes find themselves the subject of on-going micro-discriminations from their peers—both male and female, albeit in different ways. It seems likely that there would be a value in making students explicitly aware of and addressing their own implicit biases as part of student team work. This might include promoting self-awareness by both male and female students through taking a test for implicit biases and debriefing the results with them, and explicitly teaching students about the nature of implicit bias during preparation for group work. Although there is some evidence of resistance on behalf of faculty to dealing with gender (and other diversity) issues within advanced engineering courses that involve student team work, if we are to maximise the learning benefit of student teams for all students, then pedagogical actions in this direction seem necessary.

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