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Impact of Creating Critical Mass Classrooms for Females

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CONTEXT
For many years the makeup of Engineering Foundation Year (EFY) student groups at Curtin University has been on the premise of creating diverse groups viz. 1 mature age student, 1-2 international students, and at least two females in a group of 20. In 2016 groups were arranged to achieve a minimum of 7 females in a group where possible. The rationale for the change was based on research that indicates stereotyping and discrimination is minimised in organisations that had achieved 30-35% representation of women (Kanter, 1977 in Hurtado and Ruiz, 2012). Research indicates that numbers matter because it contributes to the perception that women have the ability to succeed in engineering (Creamer, 2012). In addition, extensive "research and evaluation by the STEM education community underscore that building a critical mass matters." (Malcom and Malcom-Piqueux, 2013, 178)

PURPOSE
The hypothesis being tested is 'Groups with a critical mass or greater of female students create an environment that supports learning and student retention by minimising discrimination and stereotyping, and maximising female verbal participation thus engagement in the classroom.'

APPROACH
Classroom observations and retention data will be used to assess the influence of group gender composition on students' performance and engagement. Mixed mode research methods will be used with a variety of data collection to enable greater validity, reduce pre-existing assumptions and test the hypothesis from a number of perspectives. Observational data will be derived from the extensive work of Elizabeth Cohen and colleagues (Stanford University) on Complex Instruction. Quantitative data will be the performance and retention data of students both prior to intervention (historical data) and after intervention (post 2016 data). Qualitative data analysis will be conducted to gain more insight into the experience of female engineering students which is difficult to obtain from survey data (Creamer, 2012).

RESULTS
It is reported that women are best supported in majority groups; "findings support the critical mass hypothesis that women are drawn to STEM fields in which they represent a majority group and suggest that gender ratios in the laboratory classroom may signal the types of foci that women adopt to ensure that certain career-related outcomes are attained." (Deemer, 2015, 67).

CONCLUSIONS
The outcome of this research will be a contribution to the teaching and learning discourse on gender. In more immediate and direct terms, the outcome will be an endorsement (or otherwise) for ongoing strategies to increase the critical mass experiences of female students (and other underrepresented students) in engineering. This could extend beyond the EFY grouping at Curtin University. Additionally the outcomes would be evidence to support gender critical mass grouping in other learning environments beyond Engineering Foundation Year.

KEYWORDS
Gender; diversity; first-year.

Introduction

For many years the makeup of the common first year Engineering Foundation Year (EFY) student groups at Curtin University has been on the premise of creating diverse classroom groups viz. 1 mature age student, 1-2 international students, and at least two females, in a group of around 20 students (19 on average, 24 maximum). The groups are allocated students on the basis of their similar academic background determined upon their prior educational exposure and achievement in mathematics, physics and chemistry. The group system is a mechanism whereby a group of around 20 students is timetabled as a whole, that is, the group of 20 students progress through the foundation year together; attending all the same lectures, workshops, laboratories and tutorials for all core units; of which there are four per semester. A group of 20 students may be combined with a second group for larger tutorials and workshops in most units. The grouping system has been attributed to the strong retention rate which has been around 95% since the inception of the EFY.

In 2016 most on-shore campus EFY groups were arranged to achieve a minimum of 7 females in a group where possible. The rationale for the change was based on research that indicates stereotyping and discrimination is minimised in organisations that had achieved 30-35% representation of women (Kanter, 1977 in Hurtado and Ruiz, 2012). Research indicates that numbers matter because it contributes to the perception that women have the ability to succeed in engineering (Creamer, 2012). In addition, extensive "research and evaluation by the STEM education community underscore that building a critical mass matters. This work also provides clues as to what effectively builds and sustains diversity." (Malcom and Malcom-Piqueux, 2013, 178). Offshore campus EFY groups were not arranged with gender composition in mind and are presently excluded from the research. Some groups at the on-shore campus have gender parity or a majority of females not by design but due to incoming students' prior subject choices and level of attainment in mathematics (the female students typically complete Specialist Mathematics at secondary school).

This research is examining the impact of the changes to the grouping system. The aim is to analyse the effect of different groups' gender composition on the female students' motivation, verbal participation, and perceptions of discrimination or stereotyping, career aspirations and engagement. In conjunction with student feedback, classroom observations and retention data will be used to assess the influence of group gender composition on students' performance and engagement. It is envisioned that the outcome will be evidence that the gender composition of groups is important to enhance student experience, engagement and retention.

Purpose

The hypothesis being tested is 'Groups with a critical mass or greater of female students create an environment that supports learning and student retention by minimising discrimination and stereotyping, and maximising female verbal participation thus engagement in the classroom.'

The 2016 on-shore campus had 16 groups with no female students, 5 groups with 5-10% females (average 7%), 4 groups with around one third females (average 35%), and 4 groups with more than 50% females (average 58%). The average group size is 19 students in 2016.

At present, more females than males attain higher ATAR in the 80+ range (80 is the minimum score for direct entry into Engineering at Curtin University); more females are enrolled in Western Australian Certificate of Education subjects (these subjects being necessary to attain a ranking for university entry). However, prerequisite and recommended subjects for engineering direct entry are predominately taken by male students. For instance, the male to female ratio of students undertaking Physics Stage 3 or Mathematics Specialist is around 3 to 1. The engineering applicant and intake is predominantly male (86% male in

2016 at Curtin University). Of the female students who enter the course directly, almost one third have taken Mathematics Specialists, hence, 3 of the 13 groups with female students were based on Mathematics Specialist prior competency and these had percentages of females of 33% (B3), 35% (B5) and 69% (A8). The groups with female students are shown in Table 1.

Table 1: Group composition 2016 – showing only groups with female students

Group Label	Number of Students	Number of Female Students	Percentage of Females
C3	20	1	5.0%
C4	17	1	5.9%
B4	16	1	6.25%
B1	20	2	10.0%
C6	19	3	15.8%
B3	18	6	33.3%
D3	20	7	35.0%
B5	17	6	35.3%
A6	24	9	37.5%
C7	19	10	52.6%
A5	20	11	55.0%
D2	20	11	55.0%
A8	13	9	69.2%

If we can enhance the EFY experience and retain more female students, the flow-on effect may increase female applicants to Curtin University engineering. This aligns with one of the key recommendations of the Australian Council of Engineering Deans in which addressing the supply and quality of engineering graduates required "increasing diversity in engineering workplaces supported by engineering education programs" (King, 2008, 18).

Whilst retention of students is very high; this has not previously been scrutinised based on gender. Student feedback consistently indicates high satisfaction with the EFY learning experience; however, feedback has previously never been scrutinised based on gender nor has feedback previously been sought that discriminates or supposes the experience may be influenced by gender or gendered compositions of groups. Full-papers are subject to a double-blind peer-review process (two reviewers will assess the paper without knowing the identity of the author(s) of the manuscript submitted, as well as the author(s) not knowing who the reviewers were). Draft papers submitted should not include author details (names, affiliations or e-mails). Before submission, authors should inspect their documents and remove any personal information that may have been embedded through the authoring word processer or PDF converter.

Approach

The framework to support this is Complex Instruction and STEM Gender research. Mixed mode research methods will be used with a variety of data collection to enable greater validity, reduce pre-existing assumptions and test the hypothesis from a number of perspectives.

Observational data will be derived from the extensive work of Elizabeth Cohen and colleagues (Stanford University) on Complex Instruction viz. participation is key to learning in groups and participation may be assessed using a systematic Teacher Observation Instrument and Whole Class Observation Instrument. The instrument has been tailored by the authors and records the whole room layout, gender compositions of groups and clusters (students working together within the group classroom), observations on participation of each cluster member for a 10 second interval over the course of the lesson. For each 10 second interval the observer records the task being undertaken (instructions, research, writing, note taking) by the cluster member. It is anticipated that there may be changes in the roles during the course of the lesson (workshop, tutorial, and laboratory) and changes in who leads activity and who is following directions. At the time of writing, 17 class room observations have been conducted. The 17 observations were: 4 x Engineering Foundations Design and Processes (Engineers without Borders design unit) workshops; 2 x Engineering Foundations Principles and Communications workshop (conceive, design, implement, operate project based unit); 1 x Materials laboratory; 1 x Materials Workshop; 1 x Electrical laboratory; 1 x Electrical tutorial; 1 x Physics workshop; 3 x Mathematics workshops; 1 x Engineering Successes and Failures workshop; and 2 x Engineering Mechanics Workshop (which was run as a traditional tutorial). The authors (and University) define Workshops as student-centred activities facilitated by a staff member, whilst Tutorials are tutor-led activities typically involving the tutor demonstrating or modelling solutions. A sample classroom cluster observation note is shown in Figure 1.

Quantitative data will be the performance and retention data of students both prior to intervention (historical data) and after intervention (post 2016 data). This data is not currently finalised; however, retention of female students from semester 1 to semester 2, 2016 is at 92.5% with attrition due to course completion, withdraw, termination or leave of absence is 7.5%.

Qualitative data analysis will be conducted to gain more insight into the experience of female engineering students which is difficult to obtain from survey data e.g. personal and broader ranging impacts on their participation and engagement such as extra-curricular options and university culture as seen in prior research (Creamer, 2012). Qualitative and quantitative Likert scale data will be sought from participants on their perceptions of their experiences in EFY groups and measures assessing experiences of stereotyping and discrimination. Data will be compared with previous research conducted in artificially created small group activities of engineering problem solving (Dasgupta et. al, 2015). At the time of writing, the survey instrument has been generated and distributed with 45 responses, of which, 10 were from female respondents. The instrument is shown in Appendix A and includes questions on age. It is anticipated that age of respondents may impact on their perceptions.

Results

The authors have not completed the observations and qualitative or quantitative analysis at the time of writing; however, preliminary data has been obtained and is discussed below.

It is interesting to note that some observations were not necessarily the focus of the research but have led to concern about unintended gendered messages being delivered in the engineering classroom. Classroom observation included the following:

Female tutors were lead tutors in 12 of the 17 classrooms observed. However, in some classrooms such as the Engineering Foundations Design and Processes (Engineers without Borders design unit) workshops, the female tutors delivered the communications aspects of the session, whereas technical support and details were provided by male tutors.

This is a function of the background of the tutors for this unit, that is, the females are all English language specialists, humanities trained, and native English speakers, whereas the male tutors are all international post graduate research students in engineering. The authors feel this gendered division of delivery reinforces stereotyping of engineering communication being the domain of female engineers only, and a devaluing of the communication and team work skills required for engineering may arise by this unconscious bias. This has been concluded by other researchers who have indicated there are stereotypically feminine competencies important to engineering that are under-rated by senior male engineers (Male, Bush and Murray 2009).

Observation Protocol

Room Layout

M (C)	F (D)	F(E)
M (B)	M (A)	F (F)

Cluster 1 Front of Room

Date
Time
Unit
Room
Group Observation 18

Observe each person for 10 seconds. Note whether they spoke (☑ if yes, ☒if no). Note their interaction with their group. Observe the next group member for 10 seconds.

			Early		*Late*			
1	A	×	Listen	✓	Off task			
	B	✓		×	Off task			
	C	×	Listen	✓	Off task			
	D	×	Listen	×	Looking @board			
	E	✓	Questioning	✓	Looking @board			
	F	×	working	×	Off task			

Figure 1 Small Cluster Observation Instrument Sample

Students self-select their small working clusters within the classroom; typically 2 to 6 students working together at a table constitute a cluster. It was observed that a cluster was slightly more likely to be all-male and those clusters that did have females in the cluster, were almost exclusively all female or more than 50% female. It should be noted that classrooms of all-male groups have been observed. The observed classrooms with mixed gender compositions had percentages of females ranging from 4% (1 out of 26) in C3 through to 78 % (7 out of 9) in A8. This reflects the makeup of the groups as designed. When asked why they had chosen to work in a particular cluster, students stated they chose people in the cluster who they knew would work at the same proficiently and level of dedication towards achieving the same goals, for example, the goal to achieve a high distinction. They felt the decision of who to work with was not based on gender; however, the female clusters all had a similar drive to achieve high grades. Whilst many variables may affect the self-selection of groups, including a negative propensity to select others with a similar learning style (Halstead and Martin 2002), the advantage of self-selected groups in engineering task-orientated activities is an enhanced sense of responsibility towards achieving a goal which can lead to enhanced “trust, cohesion and cooperation of the teams.” (Zhou and Pazos 2014, 3006).

The cluster observations can be summarised by the following: Group dynamics were influenced by personality; with extroverted students taking the lead in discussion and group talk. Introverted students of any gender tended to produce work whilst staying quietly on task. The all-female clusters tended to be more vocal and were highly engaged and motivated to get on task and remain on task. The all-female clusters had no hesitation to answer question, volunteer solutions or share to the whole group. The mixed-gender clusters that had more females than men (6 of which were observed), appeared to be led by the female students who directed activity with enthusiasm.

The motivation to change the status quo in group gender-composition was based on seminal research by Kanter (in Hurtado and Ruiz 2012) that indicates stereotyping and discrimination is minimised in organisations that had achieved 30-35% representation of women. Eight of 13 mixed gender groups were created with at least one third females in 2016; a significant change to previous practice which distributed the females equally, albeit sparsely, to all groups. Subsequent research in the Science, Technology, Engineering and Mathematics (STEM) space has supported the assertion of a critical mass as being critical women’s motivation, verbal participation and career aspirations. It is reported that women are best supported in majority groups; “The current findings support the critical mass hypothesis that women are drawn to STEM fields in which they represent a majority group and suggest that gender ratios in the laboratory classroom may signal the types of foci that women adopt to ensure that certain career-related outcomes are attained.” (Deemer, 2015, 67). Our preliminary observations also support this; hover, data collection is still ongoing and retention data will not be available until 2017.

Conclusions

The outcome of this research will be a contribution to the teaching and learning discourse on gender. In more immediate and direct terms, the outcome will be an endorsement (or otherwise) for ongoing strategies to increase the critical mass experiences of female students (and other underrepresented students) in engineering. This could extend beyond the EFY grouping at Curtin University. Additionally the outcomes would be evidence to support gender critical mass grouping in other learning environments beyond engineering foundation year. This research is examining the impact of one strategy to increase diversity. Another strategy initiated by the first author, active in 2017, is a relaxation and broadening of pre-requisite requirements. This responds to the unequal uptake of Physics and Mathematics Specialist at secondary schools which has a flow-on effect of a gendered engineering intake. The impact of these strategies combined will be more evident in 2017.

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Appendix A: Survey Instrument for Data Collection

	Thank you for participating in this survey about your experience of Engineering Foundation Year. What you say will be used to help improve the first year experiences of future students. Please take 20 minutes to provide feedback on your experience of Engineering Foundation Year (EFY), your study habits, motivation, support and experiences in engineering. This survey is in 3 parts: A. About You and Your Study B. About Group Work and Experiences in EFY C. About your motivation and support Your response is private, confidential and anonymous. In accordance with Curtin Human Research and Ethics Guidelines, a copy of the Participant Information Form can be found here PICF.pdf and the Survey Consent Form can be found here Consent.pdf (opens in new windows). Completion of an anonymous questionnaire is considered evidence of consent to participate in the study. Please click on the button below to begin the survey.
Part A: About You and Your Study	About how many hours a week do you generally spend studying? Studying may include listening to Echos, reading, research, note taking, doing practice problems, etc
	About what proportion of this study time is done with peers?
	What year of engineering are you currently enrolled in (for most enrolled units)?
	What is your current Major(s)?
	What is your age?
	What is your gender? m Male (1) m Female (2) m Other (3)
	I identify as a person of cultural, gender or language minority in EFY m True (1) m Neither true nor false (2) m False (4)
Part B: About Your Experiences in Engineering First Year	Challenge: In engineering group situations in EFY rate how you found the group work on the scale of challenge where 100 is the most challenging and 0 is the least challenging • Workshops- problem solving (1) • Unit A group tasks (2) • Unit B group tasks (3) • Laboratories - conducting labs (4)
	Threat: In engineering group situations in EFY rate how you found the group work on the scale of threat where 100 is the most threatening and 0 is the least threatening • Workshops- problem solving (1) • Unit A group tasks (2) • Unit B group tasks (3) • Laboratories - conducting labs (4)
	Have you ever experienced any of the following forms of discrimination or stereotyping? (select as many as apply) q Verbal comments (1) q Offensive visual images (2) q Exclusion (3) q Sexually suggestive behaviour, such as leering or staring (4) q Sexually explicit emails, text messages or posts on social networking sites (5) q Comments about your private life or the way you look (6) q Inflexibility regarding your need to care for children or people who depend on you for care (7) q Comments/assumptions about your (in)ability based on gender (8) q Other, or unsure, please specify below (9)
	Have you ever reported an incident of discrimination to the University or person of responsibility in the University (lecturer, tutor, counsellor, director, Head of area, etc)? m Yes (1) If you are comfortable to do so, describe the experience(s) of discrimination you have encountered:

	m No (2)
	How would you rate your group work experiences in EFY units? Strongly agree (1) Somewhat agree (2) Neither agree nor disagree (3) Somewhat disagree (4) Strongly disagree (5) € I had equal contribution to all peers (1) € I participated less than other peers (2) € My voice was heard less than other peers (3) € I participated actively (4) € I felt my gender was distinctive (5) € My input was helpful to solving problems (6)
	Think of a situation in EFY in which you had negative feelings. (Select up to 6 items that contributed to these feelings.) q It was boring (0) q It was difficult (1) q I felt disconnected to the learning (2) q The teacher did not care (3) q I was a nobody/ignored (4) q No one knew about my background or experiences (5) q I was identified/labelled negatively (6) q No one liked me or cared about me (7) q I was not good on this subject (8) q There were struggles and issues at home (9) q I could not share my thoughts or opinion (10) q I did not understand the materials (11) q No one was interested in me or my thoughts and opinions (12) q Other (13) ____________________
Part C: About Your Support, Motivations and Career Aspirations	Please respond to these questions based on your past or current experience with the recruitment and admission process. True (1)False (2) Not Applicable or Unsure (3) € I was recruited to enter the engineering profession because I am a person of gender, language and/or cultural minority (1) € I was encouraged to apply into the engineering program because of my gender (2) € I was informed that my gender was of value in the engineering profession (3) € I was told that there was a need for engineers of diverse gender, cultural and language backgrounds (4)
	€ I have/had a lecturer/professor/instructor who shared my gender/cultural/ethnic background (1) € I identify with other classmates in terms of shared experiences and commitment (2) € I have/had opportunities to discuss and share our learning (progress and challenges) with other classmates on an on-going basis (3) € I have/had a sense of true friendship and camaraderie with my peers (4) € I have/had opportunities to discuss issues relating to our gender or cultural and ethnic backgrounds and experiences with my peer group (5) € I feel that I have a voice in my classes and that my perspectives and opinions are welcomed (6) € I feel supported in expressing my opinions and perspectives (7) € I rarely felt excluded or isolated from my peers or the program (8)
	At what age did you first realize that you want to become an engineer?
	Who or what do you think were your primary forces of influence on your decision to become an engineer? (Select up to 3 items that apply the most.) q I love solving problems and using maths (1) q I had a great engineering outreach experience (2) q Someone in my family was an engineer (3) q I enjoy working with people (4) q I was good at maths and science (5) q I wanted to improve the world (6)

	What came to your mind as you thought of becoming an engineer? (Select up to 3 that are most applicable) q helping others (0) q working and helping communities (1) q having employment opportunities (2) q helping to bridge a cultural gap (3) q making a difference (4) q making my family proud (5) q doing something meaningful (6) q Other (7) ____________________
	What were the reactions of people around you when you made your final decision to become an engineer? (select as many as apply) q My parents/family were proud (0) q My parents/family were indifferent (1) q My family thought it was too difficult, too "far fetched" (2) q My family believed I could make it (3) q My friends were supportive (4) q My friends tried to talk me out of it (5) q No one had any particular or strong response (6)
	How often issues of gender are become central focus in your engineering units (reading, discussion, debate, group work, problem solving tasks etc.)? m never (1) m rarely (2) m sometimes (3) m often time (4) m all the time (5)
	Whenever issues of gender came up, I felt that I: (select as many as apply) q can discuss freely (0) q was invited to share my personal and lived experiences (1) q was encouraged to speak up (2) q was looked at as "expert" (3) q was expected to "know" everything about my gender and represent all people of my gender (4) q Other: (5) ____________________
	As a person of gender minority in engineering, I often felt that: (select as many as apply) q I have something of value to share with my classmates (1) q I have special qualities and unique experiences that will make me a more effective engineer (2) q I can readily empathize with other minority students (3) q I am no different than my peers (4) q I am less able than my peers (5) q Not applicable (6) q Anything to add: (7) ____________________
	Would you be prepared to participate in a follow up interview? m Yes (1) m No (2)