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Towards gender inclusiveness in the teaching of science and engineering subjects: A case study

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Abstract: *Despite growing awareness of the need to address issues of gender- and cultural-inclusiveness in Science and Engineering subjects, only a limited number of corresponding studies have been carried out within the Asian context. This paper reports on a case study carried out to investigate the difference in the behaviour of female and male engineering students of Asian origin, within the typical classroom context of an Australian university offshore campus. The observations are compared to descriptions of classroom dynamics in the USA and Australia. Strategies for gender inclusive instruction were developed and implemented. Classroom observations, student satisfaction questionnaires and passing rates were used to analyse the impact of the applied strategies. The outcome of the study appears to underline the success of the instructional strategies introduced to increase participation at a higher cognitive level of reluctant learners, in particular female students.*

Keywords: *Gender-inclusiveness; Science and Engineering; Asian students.*

Introduction

The under-representation of women in the fields of Science and Engineering is well documented (Parker, Rennie & Fraser, 1996) and the resulting socio-economic issues have been highlighted by numerous authors (Tai & Sadler, 2001; Ramirez & Wotipka, 2001). Ramirez and Woptika (2001, p. 232) state that “equity and economic considerations alike draw our attention to women’s enrolment pattern in these fields of study.” Gender-based wage inequity, loss of diversity in the work force and reduced national productivity are general areas of concern.

Although the enrolment of women in Science and Engineering has steadily increased over the last years, the attrition rate among female students remains considerably higher than among their male peers (Steele, James & Chait Barnett, 2002). The “masculine character” of Science and Engineering has repeatedly been identified as a possible cause for women leaving these academic areas. Different ways in which literature describes Science and Engineering as masculine are:

- Preponderance of male students. For instance, in the USA, women accounted for approximately 12% of all electronic engineering students from 1990 to 1996 (Mbarika, Sankar & Raju, 2003);
- Gender-based curricula. Curricula are developed by male instructors, resulting naturally in examples that suit better the interests and motivations of male students (Parker, Rennie & Fraser, 1996);

- Classroom dynamics. According to Kelly (cited in Harding 1996, p.7), “behaviours generated in science classes, with boys and girls acting out appropriate gender roles, [..] facilitate learning for boys but restrict it for girls”.

It should be noted that most of the studies cited above focus on research performed within a Western cultural backdrop. Only a limited number of studies on gender equity in Science and Engineering education are available within the Asian context.

Based on data from the UNESCO Statistical Yearbooks, Ramirez and Wotipka (2001) show that women’s share of Science and Engineering in Higher Education in Asia has increased only slowly from 9.1% in 1972 to 16.4% in 1992. As a comparison, the 1992 world-wide average obtained through this study was 20.7%, while the Western European average was 23.8%. Thus, on average, the preponderance of male students characterizes Asian classrooms as much as American, European or Australian classrooms.

Due to the requirements of accreditation by international bodies and as a result of international agreements on common practices (e.g., Washington Accord), Engineering curricula in Asian countries have strong analogies to the corresponding curricula used in Western countries. As a consequence, these curricula are quite often not only gender-biased but also culturally biased. Rewriting the Science and Engineering curricula in a gender- and culture-inclusive manner is a task that needs to be addressed sooner rather than later. An offshore campus of an Australian university, such as e.g. Curtin Sarawak, could become instrumental in the development of an equitable curriculum. However, the magnitude of this undertaking exceeds the scope of the study presented here.

The paper presented here will focus on the third way in which science and engineering have been described as masculine earlier in this chapter: student behavior in the classroom. The motivation underlying this study is to optimize the learning opportunities provided to female students, thereby contributing towards increased female retention rates.

By means of a case study, the difference in the behavior of female and male students of Asian origin is investigated within a typical classroom context. The observations are compared to descriptions of classroom dynamics in the USA and Australia. Strategies for gender inclusive instruction are developed and implemented. Student satisfaction questionnaires and passing rates are used as tools to quantify the success of the applied strategies. This is followed by a discussion and a conclusion.

Description and evaluation of problem encountered

The study was performed with students of Curtin University of Technology, Sarawak Campus, majoring either in Electrical Engineering, Computer System Engineering or Communication and Electronics Engineering. The particular unit taught was Physical Electronics 203. The class comprised of 30 students, of which 9 were female. The ratio of female students was therefore relatively high (30%), as compared to the international averages quoted earlier. A majority of the students were of Chinese cultural background (71%), with the other students being of either Malay, Iban, Indian or other origin.

During the first few weeks of the semester, it became apparent that the level of participation of female students differed strongly from that of their male peers. Male students clearly dominated the classroom in providing answers. Even when individual female students were invited to answer questions, they were reluctant to provide one. Female students were more likely to answer questions of low (e.g., recall) rather than high cognitive level (e.g., analysis). In some cases, female students even refused systematically to say anything at all.

Belenky, Clinchy, Goldberger, and Tarule (1986) in their study on *Women's Ways of Knowing* grouped women's perspectives on knowing into five categories ranging from "Silence" to "Constructed Knowledge". The category of silence, which is described as "a position in which women experience themselves as mindless and voiceless and subject to the whims of external authority" (Merriam & Caffarella, 1999, p.146) seems to adequatly depict the behaviour the female students described above.

Another interesting observation was the tendency of female students to group together into a solid cluster of female learners, sitting at the front-left corner of the classroom. This was surprising given that most of the students in this classroom knew each other for at least 3 to 5 semesters (5 semesters for those who had completed the Curtin Sarawak Foundation program).

Although the observations described here are of qualitative nature only, they are consistent with reports by Tobin (1996, p.123) that "in a whole-class settings, males are more involved than females" and with reports by Leder (1996, p. 97) indicating that "on average boys interact more frequently with their teachers than girls". A follow-up to the present study, focusing for instance on the analysis of videotaped sessions, could provide further insight into the level of participation of male versus female students at Curtin Sarawak.

In the mean time, the qualitative observations described above seem to indicate two inherent risks. First, if female students do not participate to the same extent as their male counterparts, they are not utilising the same level of opportunities. Encouraging female students to actively participate in the classroom will help them to develop higher-level cognitive skills. Second, Steele, James & Chait Barnett (2002) have shown that a possible cause for the high attrition rates of women in engineering is the stereotype threat, which they define as "an uncomfortable feeling that arises when people are at risk of confirming a negative stereotype in the eyes of others." It is likely that this threat is reinforced in the context of Asian culture, where students will try not to "lose face". In a cultural environment of high-context communication, the total avoidance of participation might for some female students seem to be the only manner to escape stereotype threat.

Identifying possible approaches to overcome problem

The first attempt to increase the level of feedback of female students focused on increasing the frequency of questions addressed to them. However, this direct approach was unsuccessful, as it did not change the fact that female students simply refused to answer questions. In addition, it was feared that such a strong focus on female students would result in a disadvantage to male student, who might feel left out, thus tipping the gender-bias into the other direction.

Another strategy that was considered was to break up the cluster of female students, by forcing them to distribute homogeneously across the classroom. This option however was rejected as it was felt that it would increase the sense of threat and discomfort that female students might experience and was therefore not likely to contribute to an improved learning experience.

The strategy that was finally adopted in this study was the increased use of activities that would require female participation. These activities have the advantage that they provide not only auditory and visual but also kinesthetic stimulus and are therefore beneficial not only to female students but also to their male counterparts. The hypothesis was that the increased participation of female student in such activities would eventually result in their increased participation in other classroom interactions.

Implementation stage

The activities that were introduced during the PE203 lecture included:

- *Use of perfume to demonstrate diffusion*:
  In order to demonstrate the functioning of diffusion of electrons within a solid, a bottle of perfume was brought to the classroom. A bit of perfume was sprayed at the front of the classroom and students were asked to raise their hand once they smelt the perfume. Special emphasis was put on the brand of the perfume, much to the delight of female students. A discussion followed on the pattern of diffusion observed and students were asked to apply this to predict diffusion of electrons in solids.

- *Explain the concept of holes using chairs and students* (see figure 1):
  The concept of "hole" is introduced in PE203 to describe a virtual particle used to explain the behavior of electrons in an almost full Valence Band. Instead of describing the behavior of the many ($\sim 10^{23}$) electrons that are in the Valence Band, it is easier to describe the behavior of the missing electrons, i.e. of the holes.
  To describe this concept, a row of 8 chairs was set up at the front of the classroom. Seven students (male and female) were called to sit on these chairs, leaving the right-most chair empty. A "minus" and a "plus" sign were drawn on the whiteboard behind the row of chairs to illustrate the application of an electric field. The students were then asked to act the way electrons would. Pauli's Exclusion Principle and its impact on electronic conduction was discussed (Q:"Are two students allowed to sit on the same chair?", A: No, two electrons cannot have the same quantum number, i.e. two students cannot sit on the same chair at the same time). After the seven students simulated the behavior of the electrons, the audience was asked to describe the behavior of the empty chair. Through observation, the students found that the empty chair moved from the "plus" to the "minus" sign, thus behaving like a virtual positive particle. This behavior is equivalent to the behavior of a "hole".

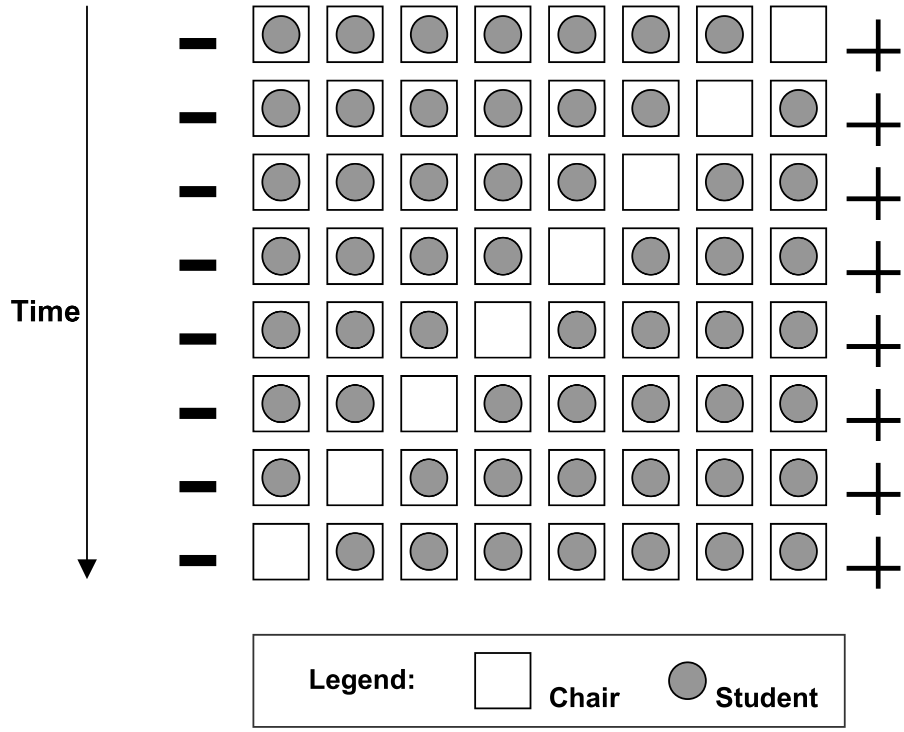

Figure 1: Schematic description of the activity used to introduce the concept of “holes”. The empty chair (“hole”) moves from the “plus” towards the “minus” sign, thus behaving like a positive particle

- *Explain the behavior of a pn junction using students* (see Figure 2):
  An important learning outcome of PE203 is the understanding of the behaviour of pn junctions, i.e. diodes. In particular, after completing the PE203 unit, students should be able to explain how the behavior of electrons in a solid (microscopic level) results in the measured current-voltage characteristics of diodes (macroscopic level).
  In a pn junction, a p-type material (with a majority of holes as charge carriers) is juxtaposed to a n-type material (with a majority of electrons as charge carriers). This results in a complex set of physical processes that include diffusion of particles, annihilation of electron-hole pairs, appearance of a built-in electric field and electronic depletion region at the interface of the junction.
  The activity that was introduced to explain the working of a pn junction involved all students. Female students were asked to play the role of electrons and were evenly distributed in the left half of the classroom. Male students were asked to play the role of holes and were evenly distributed in the right half of the classroom. Then, students were asked to act out the behavior of the charged particles that they represented and to explain and justify each movement, thereby developing higher level cognitive skills.

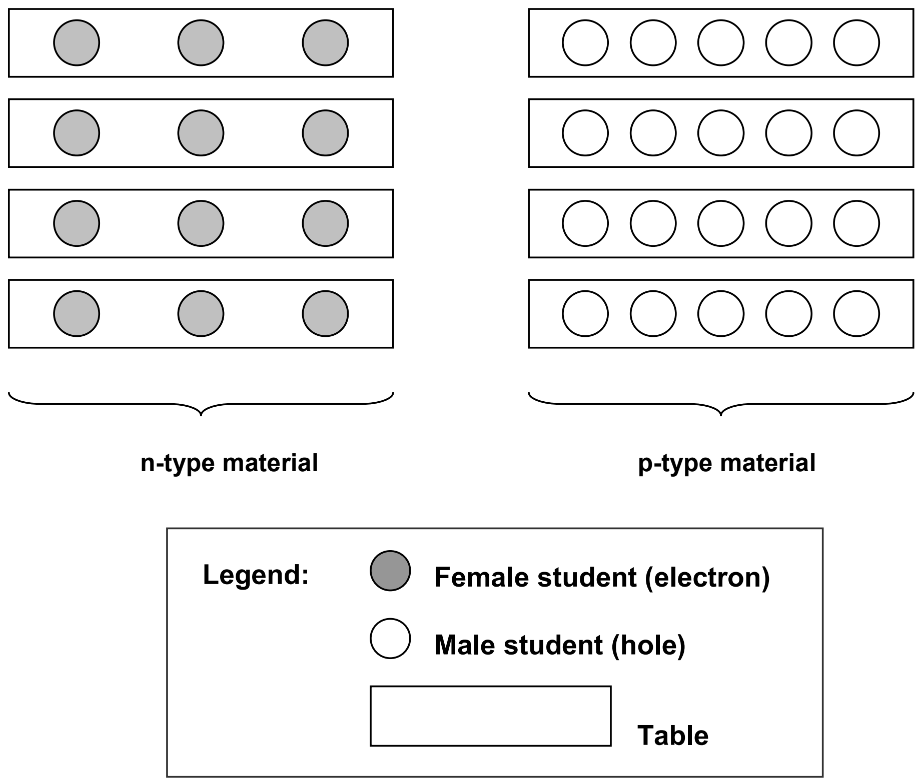

Figure 2: Schematic representation of the initial setup used to describe the behavior of the pn-junction

During the activities described above, it was observed that female students participated to a similar extent as male students. This was partly due to the fact that female students had to play out a role and could not avoid participation. At the same time, female students appeared to feel more comfortable in a student-centered environment, which would be in agreement with observations found in literature (Tobin, 1996).

Feedback

During the last week of the semester, a Students' Evaluation of Educational Quality (SEEQ) Questionnaire was distributed to the students. In addition to the standard questions of the SEEQ Questionnaire, students were asked to answer on a scale from 1 (*strongly disagree*) to 9 (*strongly agree*) the following supplementary questions:

1) "The activities performed during the lecture were fun"
2) "The activities performed during the lecture were interesting"
3) "The activities performed during the lecture helped me to understand the subject better".

A total of 23 students answered the questionnaire, of which 7 were female, 15 male, and 1 did not specify the gender.

The average result for the three supplementary questions is shown in Table 1:

Table 1: Overview of feedback obtained for supplementary questions

The activities performed during the lecture ..	**Female**	**Male**	**Significance level p**
.. were fun	7.7	6.2	0.03
.. were interesting	8.0	6.4	0.016
.. helped me to understand the subject better	8.1	7.2	0.14

Despite the small number of students involved in this study, the feedback obtained through SEEQ clearly shows that female students displayed a stronger preference than their male counterparts for the activities performed during the lecture.

In contrast to these clearly gender-specific results, all questions focusing on Group Interaction obtained similar ratings from both female and male students.

The questions on Group Interaction included:

1) "Students were encouraged to participate in class discussions"
2) "Students were invited to share their ideas and knowledge"
3) "Students were encouraged to ask questions and were given meaningful answers"
4) "Students were encouraged to express their own ideas and/or question the staff member"

The average feedback was 7.3 for female students and 7.8 for male students. Based on these result, it can be said that male students did not feel disadvantaged with respect to Group Interactions, despite a conscious effort from the part of the lecturer to increase the feedback rate of female students.

None of the additional feedback provided through the closed-response form displayed a significant difference between males and females. In particular, the level of difficulty for this unit was rated almost the same by female and male students (5.0 respectively 5.2).

Discussion and further recommendations

The case study presented here indicates that gender-dynamics in classroom of Asian students in an Australian university off-shore campus is similar to what is observed in Australia and USA. In particular, the verbal feedback provided by female students was found to be less frequent and at a lower cognitive level than the feedback of their male counterparts.

The fact that female students chose a sitting arrangement that resulted in a female-only cluster of students, was rated as very indicative considering the importance of high-context communication within Asian culture. In high-context communication, much of the message is contained in non-verbal cues, such as facial expressions, body language and the general environment in which the message is expressed. Therefore, the sitting arrangement described earlier was interpreted as a strong signal of the level of discomfort experienced by female students within the existing classroom.

As described earlier, a series of activities were introduced into the curriculum of PE203 as an attempt to improve gender-inclusiveness. Based on classroom observations as well as SEEQ results, it appears that the activities had a positive instructional impact on female students in particular, as well as on male students. The feedback provided by students through SEEQ questionnaires indicates that the instructional strategies introduced in this study lead to a perceived learning improvement independently of the gender of the students.

This finding is confirmed by the passing rates and average semester marks shown in Table 2. Passing rates for this unit were high, with female students performing better than their male counterpart. Due to the lack of a control group, it is not possible to judge whether female students would have performed equally well without the introduction of the instructional strategies described here.

Table 2: Overview of student performance in PE203

Students	Passing rate	Average semester mark
Female	100%	65%
Male	85%	56%

Despite the fact that the study presented here was performed on a relatively small group of students, a similar approach to teaching Science and Engineering subjects could be introduced with larger classes too. While some activities can easily be introduced in the context of lectures with a large number of students, others could be presented in smaller tutorial classes to ensure maximum participation of students.

Conclusions

In conclusion, the case study presented here has highlighted the importance of gender-inclusiveness in the teaching of Science and Engineering subjects within the Asian context. The participation of female students in a typical engineering classroom at an Australian university offshore campus was observed to be less frequent and at a lower cognitive level than for their male peers. In addition, classroom dynamics seemed to indicate that female students experienced a high level of discomfort, which was believed to be founded in stereotype threat. Kinesthetic stimulus introduced through a range of classroom activities helped to increase the participation of reluctant female learners. It was observed that, within the framework of an activity, female students were more likely to participate in discussions that aimed at developing a deeper understanding of the course content.
Further research is required to qualitatively and quantitatively describe the types of interaction occurring in a typical engineering classroom within the Asian context. It is hoped that the information gained through gender-inclusiveness studies like the one presented here will contribute to an increased retention rates of female engineering students in Asia.

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