Spatial Ability Performance of Female Engineering Students

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***Abstract**: This paper reports on studies conducted to evaluate the spatial understanding of female engineering students across a range of spatial tasks. Spatial ability is considered a fundamental skill in design-based disciplines and is often seen as a predictor of success in engineering graphics courses. Participants were novice female engineering students undertaking a first year introductory graphical communication course. Results are compared with previous studies that consistently show a gender bias favouring males. This paper profiles the performance of novice female engineering students on a psychometric test of 3D ability consisting of 12 different subtests and six test items in each. Issues associated with improving performance are also raised.*

Introduction

In 2008 (Williams A., Sutton K and Allen, R.) we reported the findings of a preliminary study into the issues of Spatial Ability in Engineering students. Since this time we have progressed the study and have identified a range of significant factors as well as some trends that raise further questions which need exploration. An issue that was identified in the initial study was that of the differences in spatial ability between male and female students, but for the purpose of this paper we will consider engineering students. The initial study identified that there were trends indicating female engineering students had lower spatial abilities than those of their male peers. In this paper we report on a more significant study of spatial ability, specifically reporting on the outcomes of female engineering students, the results raise a number of issues including:

- Does female spatial ability reduce the levels of interest in studying engineering?
- Do we need to address female engineering students' spatial ability competencies to enhance their success?

Importance of Spatial Ability

One of the more important aptitudes for students studying engineering courses is spatial ability, often referred to as simply visualisation. Spatial ability can be defined (Sutton and Williams 2007) as the performance on tasks that require:

- the mental rotation of objects,
- the ability to understand how objects appear in different positions, and
- the skill to conceptualize how objects relate to each other in space.

A substantial part of spatial ability is three-dimensional (3D) understanding. 3D understanding is the ability to extract information about 3D properties from two-dimensional (2D) representations (Sutton, Heathcote, and Bore, 2005). This skill requires perceptual abilities to interpret what is seen, and spatial abilities to mentally manipulate graphical representations.

Sorby (2006) reports evidence that 3D spatial skills are critical to success in a variety of careers, including engineering. Her research reveals the importance of advanced spatial reasoning and visualisation skills to these disciplines, although these skills are not handled well by many novices. There is also evidence of high failure rates in these types of courses and evidence to support the value of early spatial ability training. Sorby also identified a gender bias against females in spatial performance. These findings motivated further research into higher spatial thinking (Sutton and Williams, 2006) with specific interest in design based disciplines such as Engineering.

Women in Engineering

By the late nineteenth century, a very small number of women began entering Australian universities and other tertiary institutions in order to gain professional qualifications, particularly in areas such as teaching, nursing, medicine, science, architecture and pharmacy (Nugent, 2002). This was the start of a change in women's employment, with greater entry into professional roles. Since the 1950s women's participation in the paid workforce has grown substantially. Women now comprise 59 per cent of all domestic and 49 per cent of all overseas Australian university course completions; proportions which have been relatively constant since the 1990s (Department of Education, Employment and Workplace Relations, 2009).

Engineering is one of the most male-dominated industries in Australia while female enrolment in previously male-dominated tertiary courses such as medicine and law has risen dramatically, their participation in engineering courses has remained relatively low. No doubt there are many reasons for the lack of participation of females in engineering education and if this issue is to be addressed in the longer term then all potential strategies for the enhancement of participation of women in engineering must be considered. The potential impact of spatial abilities on women's participation in and success in engineering require consideration.

Spatial Ability

One of the more important aptitudes for students studying design courses is spatial ability. Spatial ability can be defined as the performance on tasks that require mental rotation of objects, the ability to understand how objects appear in different positions and how they relate to each other in space. Design students require the ability to think and reason in 3D by drawing conclusions from a set of 2D drawings based on a notational system. Blasko, Holliday-Darr, Mace & Blasko-Drabik (2004) report on a concern at Penn State Erie College about low grades and high dropout rates in an engineering program they offered. Despite high grades at secondary level, students appeared to be deficient in basic spatial ability. Blasko and Holliday-Darr (1999) tested incoming engineering students on a number of variables thought to influence achievement and retention in first year engineering courses such as educational background, motivation, verbal reasoning and spatial ability. They found that a strong predictor of success was performance on basic spatial cognition tasks.

The Comparative Study of Gender Spatial Ability

The study, of design students spatial ability attributes, conducted over the past 3 years has yielded a range of interesting and, in some cases significant, results. The results reported in this paper were for those achieved by first year engineering students (mech eng = 47, chem eng = 30, mtronics = 13). When considering the performance of females engineering in comparison to their male peers it become apparent that there are significant differences in their performance at the tests dealing with different aspects of spatial ability. Firstly in overall performance across the range of tests, 12 tests evaluating the range of spatial ability, female engineering students did not perform to the same level in any of the 12 tests, see Figure 1, which shows the level of performance by gender.

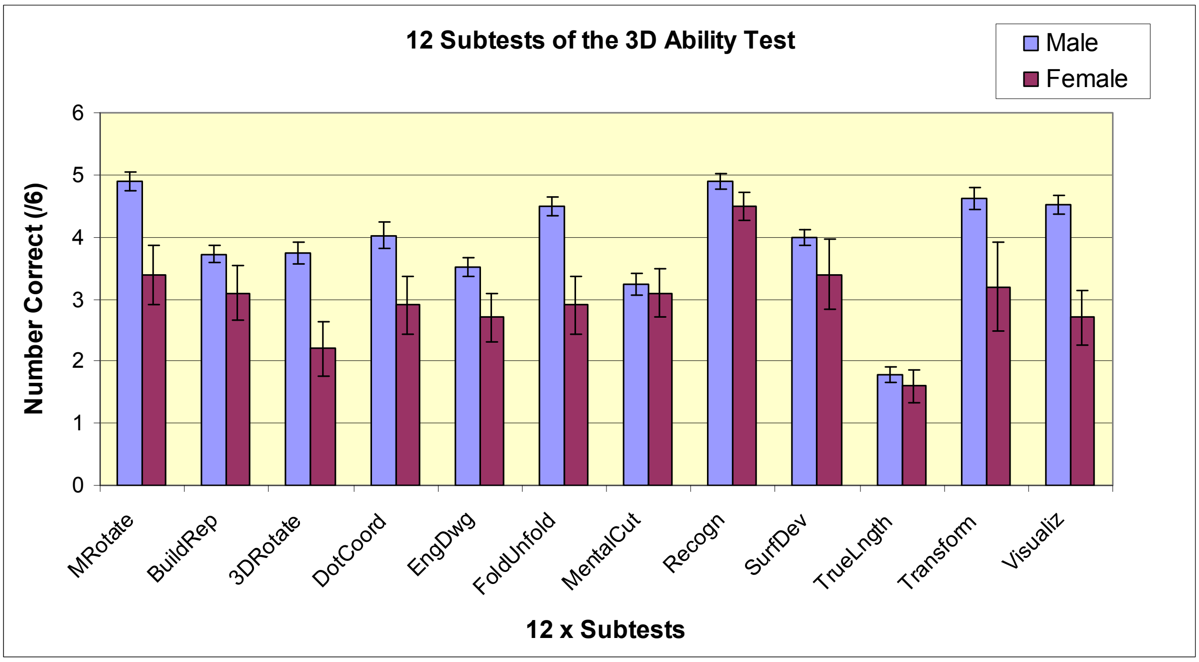

Figure 1: 3D Ability Test Results by Gender

What is evidenced in these results is that the female engineering students did not perform as well in any singular test. When the group of tests are considered as a whole then the significance of the difference is even more apparent, as is demonstrated in Figure 2.

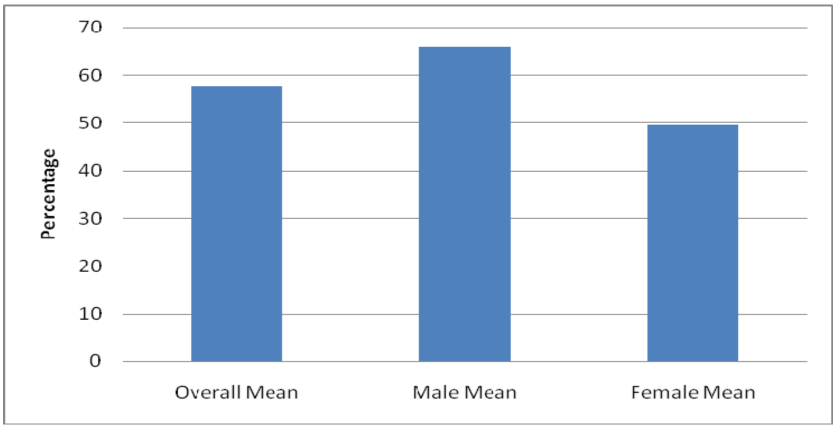

Figure 2: Spatial Diagnostic Outcomes by Gender

The group of 12 test results when combined show that the overall mean was 58% with the males having a mean of 66% and females 50%. Females did not achieve near the same levels as their male peers. The results represent a first year cohort and what is apparent from these results is that the female students would have more difficulty with subjects which involve spatial ability aspects, such subjects would include drawing and in some disciplines design subjects that involve understanding shapes and their relationship to each other. Across the 12 subtests there were ranges of spatial ability competencies which proved more difficult for female students than the other tests, these results are shown in Table 1.

	MRotate	3DRotate	FoldUnfold	Transform	Visualiz
Male					
N	80	80	80	80	80
M	4.90	3.74	4.49	4.61	4.53
SD	1.32	1.60	1.29	1.59	1.31
Std Error	0.15	0.18	0.14	0.18	0.15
Female					
N	10	10	10	10	10
M	3.40	2.20	2.90	3.20	2.70
SD	1.51	1.40	1.45	2.25	1.42
Std Error	0.48	0.44	0.46	0.71	0.45
P Value	0.001	0.005	0.001	0.013	0.000
Effect Size	1.12	0.98	1.21	0.84	1.38

P values < .05 are statistically significant.
Effect sizes (practical significance) > 0.8 are considered large.

Table 1: Tests in which Greatest Differences Occurred

The performance of females across these fields is significantly lower than the males showing that females would find concepts that require such cognitive processes more difficult. It could not be expected that female students would be able to function at the same level when dealing with problems of this type. Examples of the types of problems which test the abilities in these fields are shown in Figure 3.

Conclusion

The results reported in this paper are drawn from a study which will be ongoing, there will be other disciplines and other institutions involved in the future. What these results indicate is that females do experience more difficulty than their male peers when dealing with spatial problems. The fact that it is so comprehensive, in all 12 tests, raises a range of issues. As universities work toward increasing the representation of females in the engineering programmes there will need to be consideration given to prepare females for work in areas that requires spatial abilities.

Although not within the remit of universities the preparation of students for university courses which utilise spatial abilities needs to be a consideration of the secondary and perhaps even primary school sector. Indications are that with appropriate experiences females are able to improve their abilities in this area.

Universities need to consider the abilities of female students when they enter design based courses or courses which would require application of spatial abilities. Curricula need to include experiences for females to that they are able to participate fully in the subjects which involve design or drawing and problem solving requiring spatial abilities.

At this point of time the spatial ability study is continuing, but also it is entering a phase where approaches to improve or enhance spatial abilities are being developed. It is planned that there will be a release of materials and resources through the Australian Learning and Teaching Council of materials developed as an outcome of this research project. It is hoped that engineering educators are able to respond to the issues identified in this study and improve both its attraction of females to the profession and more fully support them as they study in the courses.

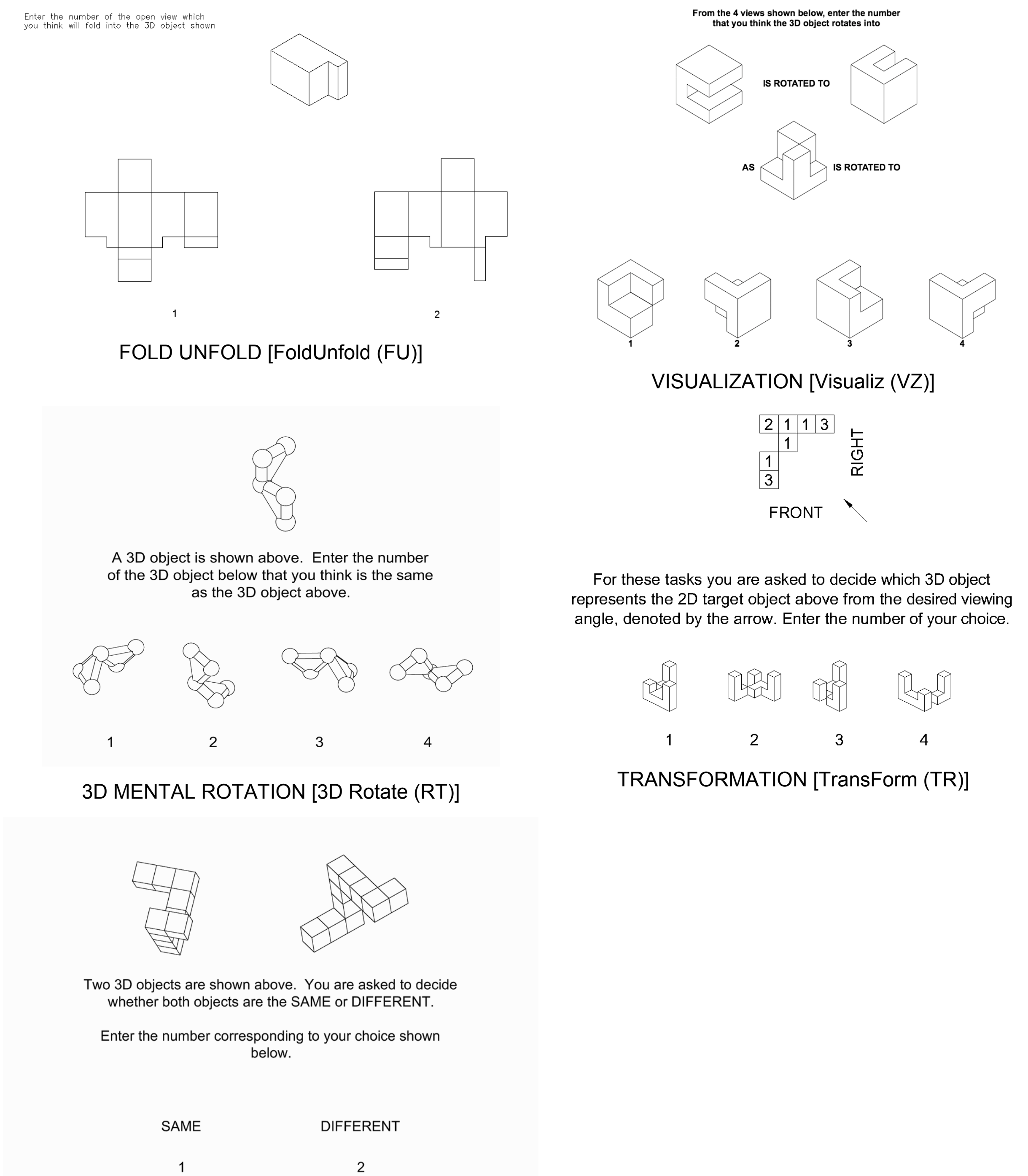

Figure 3: Examples of Questions

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