

CULTURALLY INFLUENCED LEARNING: WHY DO SOME STUDENTS HAVE DIFFICULTIES VISUALISING IN 3D?

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ABSTRACT

This study is a continuation of a developing interest in the observed problems of a group of engineering students undertaking a first year BEng course in Mechanical Engineering, and in particular a module in Computer Aided Engineering and Design. A previous study had noted that some students arrive on the engineering course with a range of abilities in drawing and 3D (spatial) visualisation, and that these difficulties can be a significant barrier for progress. Other studies have shown that spatial visualization is a significant predictor for success on engineering courses, and that the ability to visualize objects, forces, moments and effects on physical bodies is vital to the development of core engineering skills. A significant number of students on the course are from overseas, and during the initial study it appeared that these students were more prone to experience difficulties in spatial visualization, as measured using a standardized test. Methods were evaluated to help these students improve, and these proved successful. This paper presents the latest results from the continued study, which explores a hypothesis that earlier learning and exposure to drawing, both Art and engineering, influences core spatial visualization, and that cultures which focus on traditional mathematical and science skills, may create issues for some students with respect to spatial visualisation. The study also incorporated analysis of a group of Product Design students with a very different profile in terms of their exposure to Art and drawing and their cultural background, as a means of providing contrast to the initial study.

Keywords: improving spatial visualisation, 3D visualisation, culturally influenced learning, education

1 INTRODUCTION

1.1 Importance of spatial visualization in Engineering

Tertiary education in engineering focuses to a large extent on the development of core analytical skills, and therefore selection for these courses relies on evidence of a knowledge and aptitude in the mathematical and physical sciences. Course selection does not generally specify any requirements in drawing or even specific engineering or technical drawing skills. Only if Design is featured as a major course element is there perhaps any specified need. However, there is significant evidence that an ability to visualize objects in 3D, and relate these within a spatial framework is vital to the development of engineering skills. Sorby states that “Researchers have found that 3D spatial skills are critical to success in a variety of careers, particularly in engineering and science” [1], and more specifically “spatial visualization or the ability to perform complex mental manipulation of objects has been established as a predictor of success in several technology related disciplines” [2].

How can engineers correctly apply their mathematical modeling skills in the physical world, if they struggle to correctly visualize the complex multi-dimensional problems they encounter? Spatial visualization (S.V.) is the term applied to the ability to create accurate mental models of the physical world. It is this skill that allows humans to imagine the relationships between objects, predict changes and movement and dependencies, as well as relate their position within their environment.

1.2 Prior research – The previous study

An initial study was carried out to investigate observations that some students on a first year Computer Aided Engineering and Design course, within a Mechanical Engineering degree at the University of XXXX, had significant problems with visualizing objects, particularly when creating orthographic drawings of engineering components. It was not clear why these students struggled to be able to correctly relate the features within the objects and draw these in 2D planes correctly.

The class of 140 students had a significant overseas component, mostly from the Middle East and North Africa (MENA). It appeared that most of the observed problems were from this group of students.

At that stage the focus was on identifying ways of measuring their core spatial skills and techniques to quickly improve this as a means of removing this barrier to successful course completion. It had been observed that some students in previous years had indeed continued to struggle, and in fact this represented a major barrier to their overall course progression.

A literature search was undertaken to identify methods for measuring spatial visualization, and also best practice thinking on how to improve this most effectively.

Sorby [3] reported that Gimmestad in 1989 found that the Purdue Spatial Visualisation Test: Rotations (PSVT-R) was the most significant predictor of success in a study conducted at the Michigan Technological University (MTU).

Details of the test were sourced and the class tested using the PSVT-R. A group of students with low scores (lower than 60% threshold) were identified and these correlated well with the students experiencing difficulties with engineering drawing. These students were invited to take part in a voluntary 9 week, 2hr per week support class designed to improve their S.V. ability. The test was also used at three week intervals in order to measure any changes in S.V.

A variety of techniques were tried:

1. Use of a computer software program created by MTU to develop S.V.
2. Using SolidWorks 3D models to explore the relationships between features and orthographic views.
3. A technique developed at the university of XXXX called ‘blind sketching’, where participants were invited to develop sketches of objects hidden in a bag, and explored only through touch.

The workbook and software was provided by Delmar CENGAGE Learning ‘Introduction to 3D spatial visualization an active approach’ by Sorby and Wysocki [4].

The students used solid models of three dimensional parts using SolidWorks, exploring these by rotating the objects and creating cross-sections with a series of exercises based on existing solid models as shown in Figure 1 below.

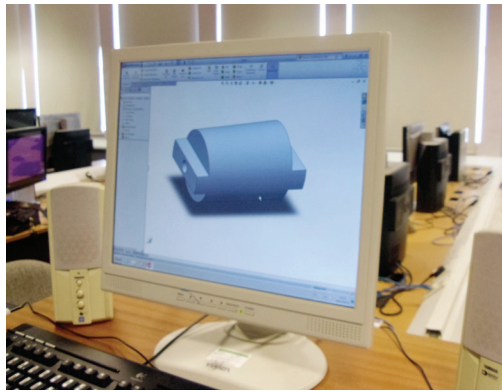


Figure 1. Exploring 3D using Solid models

The ‘blind’ test involved students having to sketch a 3D component in a bag (Figure 2), where they were only allowed to explore its features by touch, and therefore construct a purely mental visual picture of the part from which to then draw a series of views.



Figure 2. Examples of the physical parts for the ‘blind’ sketching exercises

The Mechanical Engineering class consisted of 116 students, of which 5% were female and 26% from African, Middle Eastern or Asian origin, with the majority of the class from Europe. Of this class, 51 students sat the PSVT-R test and 15 students were identified with a score of 60% or less. These students were invited to take part in voluntary support classes. After three classes the students were re-tested using the PSVT-R and the results shown in table 1.

Table 1. PSVTR Results

Group	Average	Standard deviation
ME111 whole class (51)	74.7%	17.6%
Support Group (pre classes)	53.6%	12.3%
Support Group (3 classes)	70.8%	16.0%

The significant improvement in the support group was similar to studies identified in the literature search where improvements can be seen within similar timescales, and with similar periods of study.

Even with this short period of support study, most of the students showed a significant improvement in PSVT-R score with the average improving from 53.6% to 70.8%. This was compared with other studies as shown below.

Table 2. PSVTR results from other published studies

Group	Pre classes	Post classes	Study
PoN	52.2%	63.8%	Ault and John 2010
Purdue	66.7%	80.0%	Harris 2009
VSU	52.2%	74.7%	Study 2006
MTU	51.0%	78.0%	Sorby 2007

The study had been a success in finding a reliable method for measuring S.V. and identifying strategies to successfully improve this skill.

It was decided to continue the study in future years to determine if the observation that more of the MENA students exhibited difficulties was valid, and to identify reasons for this.

An observation had also been made that the blind sketching had proved particularly effective. It was apparent that students were forced to mentally visualize the objects, and the same students were observed manipulating the imagined objects. The conversion of students from 'guessing strategies' to imagined mental images (Figure 3), seemed important in developing S.V., and this required further study to identify best practice learning strategies.



Figure 3.
Student 'visualising' an object rotation

1.3 Factors influencing spatial visualization

A number of studies have identified several factors including age, gender, individual differences and experiences that impact visualization ability [5]. Gender in particular is well documented, and the initial research at MTU was in response to a need to develop strategies to improve S.V. for female students. However, research into other factors is less well defined.

The study by Ault and John of a group of Namibian students [6] demonstrated that there appeared to be a significant difference between comparable groups of engineering students in Namibia and their western counterparts in the US. However, there is little available research that explores this further, or any possible reasons for this observed difference. This has now become a focus for continued research at the University XXXX, particularly as the number of overseas students has been increasing in recent years.

1.4 Culturally influenced learning

There is a significant volume of research in the cultural differences between Asian and western students. These are described as Confucian and non Confucian approaches to learning, with what is

often noted as a more rote approach to teaching and learning in the Asian Confucian cultures. However, Biggs [7], and others [8] [9] have commented that these apparent surface approaches to learning do not prevent Asian students adopting deeper learning strategies, and in fact Asian students are out performing Western students on many courses.

The same level of research does not appear to be available regarding the approaches to teaching and learning in the MENA countries, but there is anecdotal evidence that more didactic teaching strategies are commonly used in developing countries. Cultures with a strong religious teaching element tend to focus on rote learning initially, and there may be some comparison with the Confucian teaching cultures.

Art in the Middle East appears to be a more geometric design activity with less rendered object form. A hypothesis was formed that developing cultures that required success in engineering promoted traditional subjects such as Mathematics and science, and students had a reduced exposure to drawing and sketching 3D form. This may create a disadvantage for many students with reduced S.V. skills when eventually undertaking an engineering degree.

1.5 Engineering and Product Design

Two quite different groups were available for the study. It had already been observed in the earlier study that the average PSVT-R score of the first year Mechanical Engineering students was lower than that of a group of first year Product Design students. There were two observed differences between these groups:

1. The Mechanical Engineering students had a significant proportion of overseas students compared to the almost 100% UK and European Product Design student base.
2. Product Design students are interviewed for the course, and must demonstrate sketching, design and practical making skills for course entry.

1.6 Study Objectives

A number of key questions were identified for the study:

1. Is exposure to art, sketching and drawing, including engineering drawing, a positive factor in developing S.V.?
2. If so, is it true that MENA countries do not encourage these skills in their educational systems, favouring traditional subjects such as Maths and Science, and thus disadvantaging their students for more applied subjects, such as Engineering and Design?
3. Is the haptic 'blind drawing' activity more effective in developing S.V. than visual based approaches such as using computer models, and 2D representations of objects as used in training workbooks?

2 METHOD

2.1 Testing Spatial Visualisation (S.V.)

The various groups of students were tested using the Purdue Spatial Visualisation Test – Rotation (PSVT-R) developed by Bodner and Guay [10]. This test consists of a 30 question multiple choice timed paper (20 mins), where an isometric view of an object is shown in two states, an original position, and after undergoing single or multiple rotations. A different object is shown, and the student

asked to select the correct response from five possible answers using the same rotation or a series of rotations. An example is shown in Figure 4. To successfully answer, the student needs to be able to visualize the object in 3D and correctly manipulate this mental image.

The suggested threshold for the test is 60% correct responses, out of the standard 30 questions.

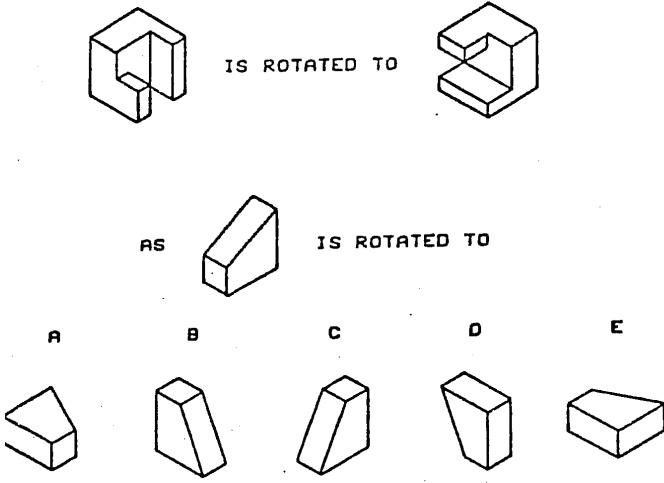


Figure 4. Example from PSVT-R Test

2.2 The Study

The mechanical engineering students were invited to take part in the study and undertake the PSVT-R test. In addition the students were asked to indicate the countries where they had undertaken their primary and their secondary education. They were also asked if they had received any formal or informal Art, drawing or engineering drawing classes.

The Product Design students from the first, second and final years of their undergraduate degree were invited to undertake the PSVT-R test. The students were also asked about their experiences in sketching and any relevant engineering drawing classes.

3 RESULTS

The results from the PSVT-R tests between the groups are summarized below in table 3.

Table 3. PSVTR results from the latest group studies

Group	Average	Standard deviation
Mech. Eng. – Year 1	70%	19.8%
Prod. Des. – Year 1	77%	11.6%
Prod. Des. – Year 2	75%	13.2%
Prod. Des. – Year 3	82%	11.1%

28% of the Mechanical Engineering class scored below the 60% threshold and have been invited to take part in the support classes, and investigation into the effectiveness of the various improvement

techniques. The lowest score received was 20%. This study is on going at present and no conclusions have been drawn at this point.

This contrasts with the Product Design groups. In the first year group, four students did not meet the threshold (18% of the group) with the lowest mark received at 43%. In year 2, three students did not meet the threshold (15% of the group), with a lowest score of 53%, and finally in year 3 all the students met the threshold score. This does indicate an increasing S.V. ability as student's progress through the Product Design course.

35 Mechanical Engineering students failed the PSVT-R threshold out of 124 students that took part in the study (28%). 15 of these students were from MENA countries, 7 from the UK, 5 from Europe, 3 from Eastern Europe, 3 from Asia, 1 from South America and 1 from South Africa.

4 DISCUSSION AND CONCLUSIONS

While the largest problem group are from the MENA countries, the results were not as marked as anticipated, and there were further quite surprising findings. Of the 15 MENA students with low scores, 8 of these indicated that they had undertaken formal or informal classes in drawing or engineering drawing specifically. From the 35 students identified, only 12 of these indicated that they had no previous exposure to drawing or sketching.

Interestingly 27 students scored 90% or greater, and of these 6 students indicated that they had not undertaken any formal or informal drawing classes.

In summary, 34% of students with a score lower than the threshold mark indicated they had no drawing experience, and of the students scoring 90% or greater, 22% indicated that they had no previous drawing experience.

It was also clear looking at students from Kuwait that all had received some formal drawing training, but this group included students with very high PSVT-R scores, as well as students with scores lower than the threshold.

Some further observations were made of Mechanical Engineering students who provided more detail on their educational background and experience of drawing. Two students in the below threshold group were able to show drawing portfolios demonstrating very good sketching skills, and both had undertaken formal Art and drawing classes. In addition, one of the year 2 Product Design students that failed to meet threshold showed evidence of having completed an engineering drawing course including orthographic projection and cut planes.

Further analysis and investigation is on-going, but the results to date do surprisingly indicate that the correlation between drawing and S.V. is not as marked as expected, and it would appear that there are other significant factors involved.

One first year student who entered Product Design as a mature student from industry, and who had previously trained as an electrician wiring houses and Industrial units, scored 100%. This student had not undertaken any formal drawing classes, and his sketching portfolio was weaker than average. His occupation had relied on his ability to relate his position within the building and it's hidden structure, allowing him to feed cable effectively from one point to another.

The observations from the effectiveness of the practical blind drawing activities indicate perhaps that spatial visualization is trained more from actual physical spatial tasks, and while engineering drawing, orthographic projection and a students ability to visualize forces etc. is manifest as a result on paper, or a 2D computer screen, training using drawing or 2D methods to represent the 3D world is perhaps not so effective. It may be that it is not a lack of exposure to drawing or Art that affects MENA students, but rather a lack of practical hands on making or problem solving. Certainly all Product Design students need to demonstrate practical design and problem solving skills within their design

portfolio, and it is perhaps student's skills developing in these areas that improve S.V. This is perhaps the reason that S.V. improves as students progress through the Product Design course, where their practical problem solving skills in design are manifest in more complex prototype construction.

The study is now being modified to investigate this further. The desire is that students entering Engineering courses at the university can be tested on entry, and effective practical courses developed to quickly improve this skill before it becomes a barrier to successful progression. The hypothesis has been modified to the reason that students exhibit lower S.V. ability is related to how much practical spatial problem solving they have been exposed to. Practical hands on tasks may build this ability more than any visualization tasks, or tasks that rely on drawing, and the reason that a proportion of overseas students seem to have lower S.V. skill is that their educational experience has been less practical than in other cultures.

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