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Spatial skills of engineering students in the United Arab Emirates

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ABSTRACT

Spatial skills are known to be important to success in engineering, and in particular, to success in engineering graphics/CAD courses. Recent studies demonstrate the link between spatial skills and creativity and innovation. Student spatial skills have been widely studied in the U.S., but work in this area in other parts of the world has been somewhat limited. In a recent data analysis in the U.S, the spatial skills of students by region of origin were examined and it was found that students from Africa, India, and the Middle East tended to have weaker spatial skills when compared to domestic students; however, it is unknown whether this is merely a reflection of the student population who chooses study in the U.S. or if it is generally true for the populations in these regions. In this study, we examined the spatial skills of second year engineering students at the Petroleum Institute in the United Arab Emirates. This paper will outline our findings, comparing the spatial skills of students in the UAE to those in the U.S. We will also include data regarding the correlation between spatial skills and performance in a second-year design course at the Petroleum Institute and will describe differences in educational systems between the two countries.

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BACKGROUND

Numerous studies have demonstrated the importance of well-developed spatial skills for success in engineering and other STEM fields[1–5]. A recent study showed the link between well-developed spatial skills and creativity and innovation[6]. In addition, the number of people in a country or region with engineering or science degrees has been shown to be an economic driver that leads to greater prosperity and a higher standard of living. The economy of the Middle East, as a region, has relied heavily on petroleum exports and while this has been a positive force in the region, visionary leaders recognize that it is not wise to rely too heavily on a single industry for economic prosperity, especially an industry that relies on a finite resource. As a result, numerous institutions of higher learning which stress engineering and science education and research have been developed in the recent past in the Middle East. These institutions include the King Abdullah University of Science and Technology in Saudi Arabia, Texas A&M at Qatar, and the Petroleum Institute in the United Arab Emirates. It is anticipated that if a greater number of citizens from these countries obtain engineering and science degrees that the economies will become more diversified and vibrant as a result.

The link between spatial skills and success in engineering has been an area of research by Sorby over the past 20 years. In a recent study, data from sixteen years was analyzed[7]. As part of this analysis, scores on the Purdue Spatial Visualization Test: Rotations (PSVT:R)[8] were examined by country/region of origin for the students. It was noted in this study that the students from the Middle East tended to have lower spatial skills when compared to American students; however, there were only a few students from the region in each year and differences may be changing through the years. Further, it is not clear that the students who attend engineering studies in the U.S. as undergraduates are representative of the general population. In addition, of the sixteen students from the Middle East for whom data was available, only two were women. For this analysis Middle East included students from Saudi Arabia (1), Kuwait (5), Cyprus (3), Iran (1), Turkey (5), and the United Arab Emirates (1). Some might argue that Turkey and Cyprus do not belong in the regional designation of "Middle East;" however, it was felt that they were more culturally similar to Middle East nations than they were to European or Asian cultures.

CURRENT STUDY

The PSVT:R was administered in the fall of 2013 to 101 (74 M; 27 F) second-year students enrolled in various engineering programs at the Petroleum Institute (PI) in the United Arab Emirates. The vast majority of the students tested were UAE nationals; 61 of the 74 males and 26 of the 27 females were from the UAE. The course is a graphics course with both CAD and hand-sketching components.
In addition to the PSVT:R scores, student scores on various assignments in the course were obtained. It should be noted that at the PI, all courses are taught separately by gender, meaning that all of the women are in sections of the second-year course that are separate from the sections taught to men.

The goal of this study is to determine if the findings for students from the Middle East in the previous study are comparable to those obtained here and to also determine if the students at the PI could benefit from spatial skills training as they undertake their engineering programs of study. In addition, in the previous study, there were only two females, so one of the goals of this study was to determine if gender differences that have been widely found in other studies, exist for this demographic as well.

FINDINGS

The average scores on the PSVT:R for students in this study as well as those from the previous study are included in Table 1. The data in this table has been disaggregated by gender, due to the fact that the

Table 1. Average PSVT:R scores for engineering students.

	White/Non-Hispanic Students (previous study)		Middle East Students (previous Study)	Petroleum Institute Students (current study)	
Gender	**M**	**F**	**M**	**M**	**F**
Sample Size	6347	1155	14	74	27
Average PSVT: R	24.44 (81.5%)	20.62 (68.7%)	15.71 (52.4%)	19.5 (65.0%)	12.19 (40.6%)
Standard Deviation	3.98	4.80	5.62	5.86	5.29

data for students from the Middle East in the previous study included only two women (they have been omitted from this analysis due to ethics considerations).

From the data presented in this table, some interesting observations are apparent:

- Highly significant ($p < 0.0001$) gender differences exist in both the US sample and the PI sample.
- The gender difference at the PI (~25%) is twice that of the gender difference in the US among White, non-Hispanic students(~12%).
- The average score on the PSVT:R for male students from the Middle East who attended college in the US is lower ($p = .0141$) than it is for the male students at the PI.
- The variance in the data for all students from the Middle East (both in the previous study and in the current study) seems to be higher than it is for the White/non-Hispanic students from the US.

In addition, we examined the correlation between scores on the PSVT:R and performance in the CAD course at the PI. For the male sections of the course, there were three variables examined: 1) total points earned on seven CAD assignments (total of 35 points), 2) score on the CAD exam for the course, and 3) overall grade earned in the course (A = 4.0, A − = 3.7, B + = 3.3, B = 3.0, etc.). Figures 1–3 show the results from this analysis.

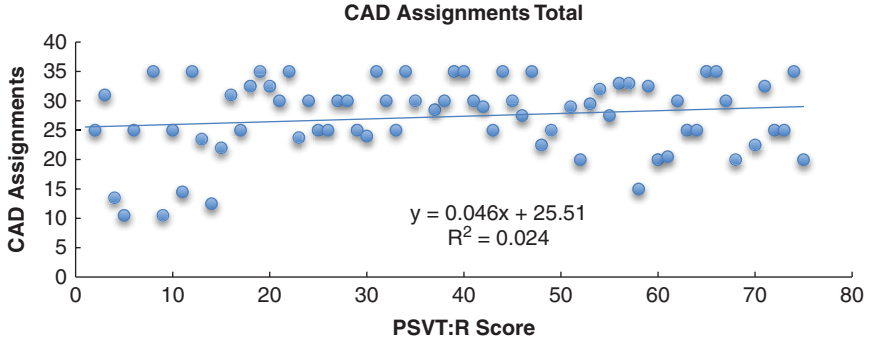

Figure 1. Correlation between CAD assignments and PSVT:R.

As it can be seen from the data presented in Figures 1–3, there is no correlation between performance in the CAD course and a student's score on the PSVT:R for the male students at the PI. For the female students, however, a different pattern emerges. Figures 4–7 show correlations between PSVT:R score and three indicators of course success: 1) score on the solid modeling portion of the graphics portfolio, 2) score on the drawings portion of the graphics portfolio, 3) CAD exam score, and 4) overall course grade.

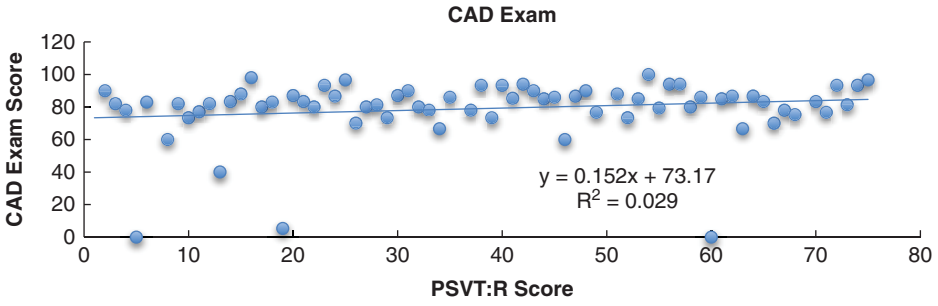

Figure 2. Correlation between CAD exam and PSVT:R.

For the female students at the PI, it does appear that there is a strong correlation between PSVT:R score and student performance in the CAD course. For the data presented in Figures 4–7, coefficients of correlation are statistically significant, or nearly so (Figure 4, $r = 0.4250$, $p = 0.057$; Figure 5, $r = 0.7174$, $p = 0.0013$; Figure 6, $r = 0.6271$, $p = 0.00617$; Figure 7, $r = 0.5984$, $p = 0.00922$).

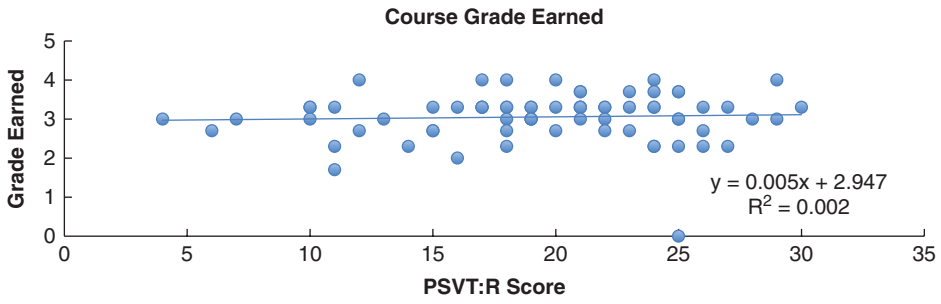

Figure 3. Correlation between course grade and PSVT:R.

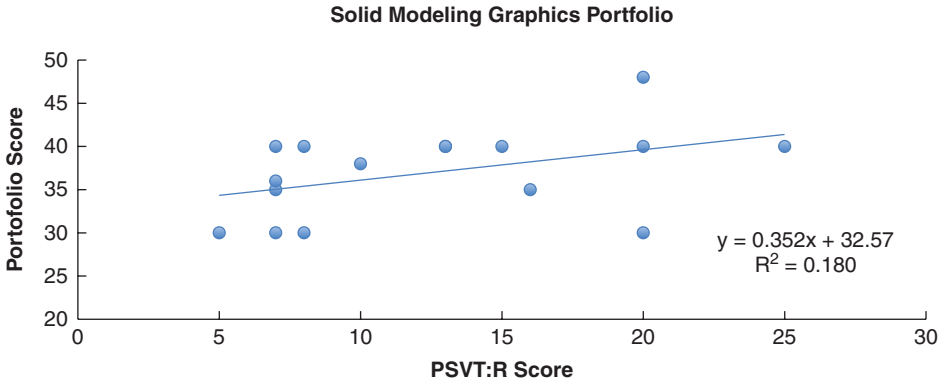

Figure 4. Correlation between Solid Modeling Portfolio and PSVT:R.

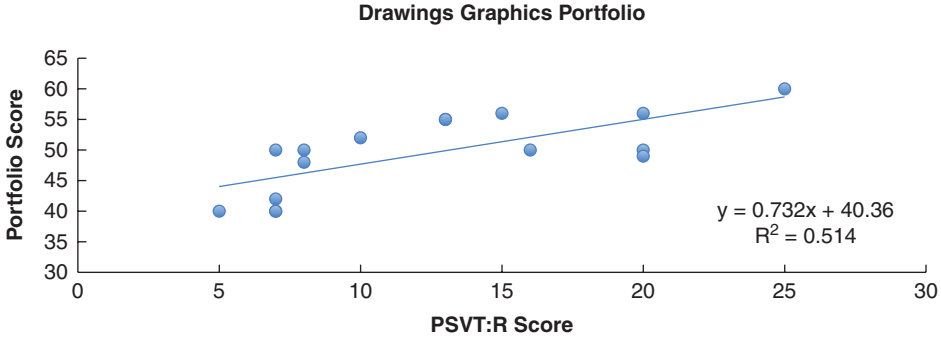

Figure 5. Correlation between drawings portfolio and PSVT:R.

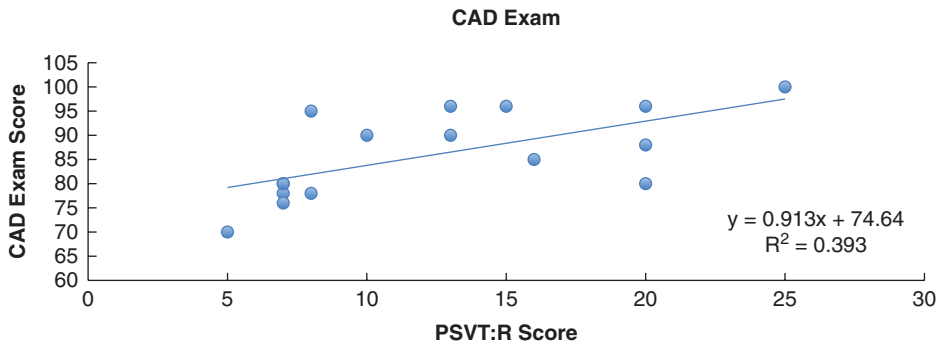

Figure 6. Correlation between CAD exam and PSVT:R.

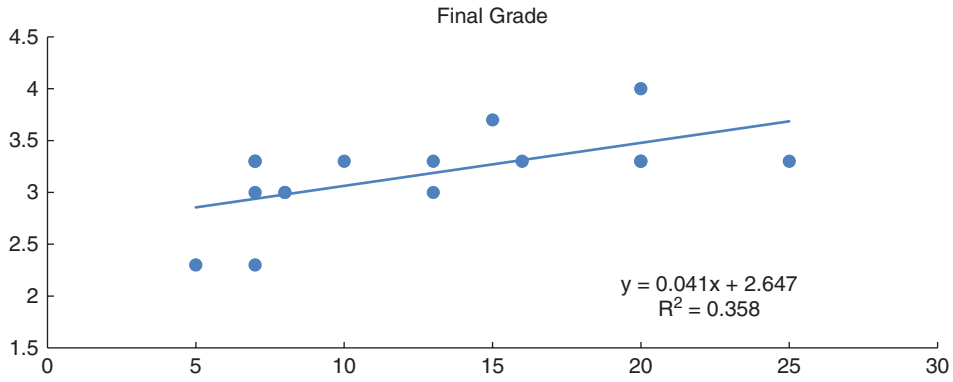

Figure 7. Correlation between Overall Grade and PSVT:R.

DISCUSSION

While some of the findings from this study were expected (i.e., significant gender differences among the UAE students), others were not. The male students at the PI exhibited stronger spatial skills than did the male students from the Middle East who attended engineering in the U.S. There are a number of theories regarding why this is the case. First, the PI students were second-year students whereas the U.S. students were tested during orientation prior to their first-year of study. This additional year of maturity spent taking highly spatial STEM courses, could have provided the PI students with the opportunity to develop their spatial skills beyond what they would have exhibited if they had been tested during their first year. Second, it could be that the students from the Middle East who attend university in the U.S. at the undergraduate level are not necessarily the "strongest" students; perhaps they are merely the more affluent students. Since no other data regarding the entrance credentials for the two sets of students are available, it is difficult to state with certainty that this is the case. Third, another theory is that students from the UAE are stronger than those from other countries in the Middle East. Recall that of the 14 students tested in the U.S., only one was from the UAE, with the remaining students coming from a wide variety of countries. The higher scores shown by the students from the PI, who were predominantly from the UAE, could be a result of better pre-college preparation in that country compared to other countries in the region.

The most discouraging result from this data is the extreme deficiency in spatial skills exhibited by the women at the PI. In spatial skills testing with middle school students in the U.S., average scores on the PSVT:R were 54%[9] – more than 10% higher than were found for female students in the UAE who were in their second year of study in an engineering program. Further, it also appears that PSVT:R scores are predictors of success for the women in the CAD course. It seems highly likely that the women in engineering at the PI are at an extreme disadvantage when it comes to success in their coursework, due to their poorly developed spatial skills.

CONCLUSIONS

Data from two studies suggests that the spatial skills of students from the Middle East are lower than those of U.S. students. It is not clear at this point in time why this is the case, however, differences in culture and in educational practices between the two countries are likely to be factors. Play with toys such as Legos and Lincoln Logs have been shown to help students develop their spatial skills and it is not clear what the extent of play with these toys are in the UAE or in other countries in the Middle East. The spatial skills of the women in the UAE are significantly behind the males in the UAE as well as the women in the U.S. Poorly developed spatial skills for these young women could be a hindrance to their successful participation in engineering curricula.

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