

Analysis of Spatial Ability Testing Results and Interior Design Program Success for Female University Students in Saudi Arabia

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Abstract

This is a longitudinal study where the Interior Design Program at Prince Mohammad bin Fahd University tested 117 incoming first year female students to determine whether spatial ability was a determinant for success in the major. Their progress in Interior Design studio classes was tracked through graduation. Although many studies in support of the importance of spatial ability for science, technology, engineering, and mathematics (STEM) majors exist, few have longitudinal data and this study focuses on females whose culture and secondary educational experience differs from students in other studies. Furthermore, the study found that while spatial ability was important for the first three studios that involved technical and hand drawing, it was performance in critical thinking, physics and mathematics that highly correlated with strong performance in later studio classes and overall success in the major.

Keywords: *Spatial Ability, Interior Design, Critical Thinking, Mathematics.*

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I. INTRODUCTION

Prince Mohammad bin Fahd University (PMU) is a small private school located in the Eastern Province of Saudi Arabia. The Interior Design Program is contained within the College of Engineering, but is a separate department situated on a segregated female campus. There are about 300, all female, Interior Design (IDES) majors. Due to increased and almost overwhelming enrollment, the university asked IDES to formulate appropriate admission standards for the program. As demonstrated in the extensive literature available on the relationship between spatial ability and STEM success, IDES felt it could be appropriate to institute spatial ability testing for incoming freshmen to determine if it would also be an indicator for females whose culture and secondary educational experience differs from students in previous studies.

II. BACKGROUND AND PURPOSE

2.1 Secondary Education in Saudi Arabia and PMU Information -

Saudi Arabia (KSA) has a unique cultural and scholastic environment that presents educational challenges as well as opportunities. Female students are taught separately from the males beginning at grade one [1, 2]. The learning interaction between genders that typically occurs in western schools is nonexistent. Although changing, instruction in Saudi Arabia elementary and secondary schools involves primarily memorization and rote learning [2-5]. Critical thinking within the society has been minimized and learning, historically, was based on accurate memorization of the Qur'an. That practice has extended into most other educational topics as well as Saudi Arabian culture where questioning or answering back to authorities is felt to be disrespectful and unacceptable behavior [5]. Successful study in STEM subjects requires extensive critical thinking skills. Saudi Arabian researchers on the topic agree that critical thinking must be incorporated into all aspects of education in the country [2-5]. Governmental plans for future education improvement recognize the need for better instructional methods and an increased focus on STEM subjects and this effort is currently in progress [6, 7].

Math training for women in secondary level public schools is optional and art education is limited. At the

secondary level, students may choose a humanities course of study or a math/science route. The humanities focus may not include math or science classes, so it is possible for young women to enter the university with no secondary level math classes. Even with math classes, the educational experience is most likely inadequate based on low KSA performance on the Trends in International Mathematics and Science Study (TIMSS) 2007 testing in comparison to other countries [8]. Art is a very confined part of the educational curriculum and the students who have taken formal art training have done so through special programs or individual tutoring. Students taught in private schools encounter a learning experience that is more similar to Western education. However, no matter their secondary educational experience, very few female students enter the PMU Interior Design program with art experience and math typically is a challenge for them.

PMU was founded in 2006 using the United States model and follows, except for gender segregation, typical western educational standards. Classes are held in English and to prepare students for college classes in English, the university has a Preparatory Program (PREP) where students become proficient in English and learn or improve their math skills. Once students complete PREP, they continue into core and major classes, typical to any Western university. Due to difficulty with math, many students delay taking the required classes and it is not unusual to find female students experiencing graduation delays because they are still trying to pass PREP math.

2.2 Spatial Ability Application-

Extensive study over many years has shown that high level spatial ability, or spatial visualization ability, is important for the academic success of STEM majors. Researchers have found that spatial ability testing is a significant indicator of achievement in the fields of mathematics, design, architecture and engineering as well as other careers that require spatial understanding such as diagnostic radiology [9-13]. Furthermore, the design thought process is separate from that used in science and even art and thus requires a distinct knowledge base and specialized instruction [14]. When students enter a program that requires spatial thinking abilities and have limited prior training to develop those abilities, it could

be important to their learning success to assess their spatial abilities especially since intervention programs have shown that spatial ability can be enhanced [15].

Studies that used the Purdue Spatial Visualization Tests: Visualization of Rotations (PSVT:R) to measure spatial ability may indicate that Middle Eastern females could have difficulty with spatial visualization. Wide-ranging research has concluded that women generally score lower on spatial ability testing than males [16-18]. Research also illustrates that Middle Eastern students tend to score lower on the test than their Western counterparts[19, 20]. In addition, Middle Eastern females score, on average, lower than Middle Eastern men [21]. Moreover, other visuospatial testing methods have found that, internationally, men tend to score higher than women. In countries, such as KSA, where the United Nations gender equity and gender empowerment indices are low, overall scores tend to be lower, and especially for women[22].

2.3 Purpose-

Interior Design is an important professional major for females in Saudi Arabia. It supplies them with a culturally acceptable profession where they can choose to work outside of the home, form their own business, or work individually on a private basis as family demands allow. At PMU, the course of study maintains the same rigor as Council for Interior Design Accreditation (CIDA) accredited schools in the United States and requires technical knowledge, spatial abilities when applying drafting, CAD and three dimensional visualizations, as well as problem solving and math calculations for space planning, adequate lighting and sustainable interior needs, material estimations, code requirements and budgets.

Knowing the secondary level educational limitations, possible spatial ability inadequacies and potential cultural effects, the purpose of this study was to determine if spatial ability and testing of a student's spatial ability would be a predictor of success for female students in an Interior Design program in Saudi Arabia. As corollaries to the main inquiry, previous art training as well as success in university level mathematics and core classes were also investigated.

III. METHODOLOGY

3.1 Testing-

For two subsequent semesters in 2013-2014, all incoming IDES students were administered a basic paper and pencil spatial ability test. Students completed the exam as an initial exercise in their first studio class- Interior Design I- taken their first semester in the program. The test used was a combination of two dimensional rotations, three dimensional visualization and spatial location problems[23]. This particular approach was employed to explore which type of spatial visualization problems would best indicate spatial ability levels. Each question type was placed into groups and analysis included overall score as well as score per group. To eliminate English language ability as a factor in test performance, the spatial ability test contained both English and Arabic instructions. The instructor who gave the exam followed written instructions on exam procedures, so each section encountered the same exam experience. Students had forty minutes to complete the questions. Students used identification numbers for anonymity and to prevent exam grader bias. A single person graded each exam by hand. Each student also answered demographic questions such as age, previous art training before attending IDES classes at PMU, and any previous IDES classes.

Groups for test questions were based on similar procedures. Groups 1 and 2 consisted of matching different types of shapes rotated two dimensionally. Group 3 involved matching three dimensional cubes to an image of the cube flattened out two dimensionally. Group 4 matched locations of holes punched into a folded paper. Group 5 entailed following written directions to locations on a map.

3.2 Tracking-

Student performance was tracked over five years. Their grades in all studio classes, core and math classes were recorded. Additionally, students who failed or changed majors were documented. From the questionnaire, information regarding previous art experience was included. This type of longitudinal study is called for in the literature to discover how further education may influence studio performance and its relationships to spatial abilities as well as other

characteristics that might better explain student success in the IDES program [24].

IV. DATA

A total of 117 female students were anonymously tested and tracked. Of the 117 students, the median age was nineteen and 20 (17%) indicated that they had art experience prior to entering the IDES program.

PMU policy is that students do not proceed into Core or major classes until they have finalized all Preparatory classes. In practice, the data indicates that many students advance without completing PREP Math. Sixty-one (52%) of students entering IDES had completed Introductory Algebra, the first PREP math class, and 33 (28%) had completed Intermediate Algebra, the second required PREP math class. So, less than a third of the students entering the program had fully completed or tested out of their PREP math classes. Of all the students, eight tested high enough on entrance exams to skip Introductory Algebra altogether, 61 students (52%), passed it on the first try, 21 students (20.5%) needed two attempts to pass, 12 required three tries, 5 needed four tries, 3 took five attempts, 3 used six tries, 2 had seven attempts and 2 passed after nine tries.

Some of the students changed majors or withdrew. Of the 117 students entering, 22 (19%) changed their major to another course of study and 4 of those who moved eventually withdrew completely from the university. Eight of these transferring students decided to alter their major after their first semester in IDES. In addition, 15 students (13%) withdrew from the university completely. All but three of the withdrawn students left after their first year in IDES. None of them continued beyond their sophomore year. To date, 78 of the students (66.67%) have completed the requirements to graduate.

4.1 Means Comparison

A basic analysis of early data and student performance in the first studio class (IDES I) was run in 2015. This is where students begin to encounter the expectations of a studio class and the interior design major. Of the 117 students, 91 passed the class and 24 either scored a non passing grade of D or F or withdrew from the class. Since most of the students who eventually withdrew completely from the university did not register for math classes, the number of students in those classes is less. Furthermore, not all students enroll in Freehand Sketching since it is an elective and can be taken at any point in the program. Table 1 shows comparison of their mean scores on several measures.

Table 1- Comparison of Performance between Students Who Fail or Pass IDES I

COMPARISONS	FAIL IDES I (24)			PASS IDES I (91)		
	Number	Mean	Standard Deviation	Number	Mean	Standard Deviation
Overall Spatial Ability Test Score	24	29.42	3.69	91	31.38	4.34
Group 1	24	21.04	2.76	91	21.86	2.77
Group 2	24	3.29	0.91	91	3.48	1.10
Group 3	24	2.21	1.25	91	2.59	1.15
Group 4	24	1.42	0.88	91	1.79	1.02
Group 5 ¹	24	1.75	0.94	74	1.65	0.94
Introductory Algebra	17	59.71	17.44	62	74.66	16.85
Intermediate Algebra	11	64.09	15.07	65	73.23	15.72
Interior Design I	24	14.83	26.37	91	84.27	9.34
Freehand Sketching	11	66.36	12.73	82	86.05	9.65
Introductory Algebra Completed	17 persons			44 persons		
Intermediate Algebra Completed	11 persons			22 persons		
Previous Art Experience	1 person			19 persons		

¹ Poor performance on Group 5 could also be a result of cultural differences. This group of questions was based on finding directions on a map. Since women in the Kingdom rarely walk to destinations and only recently were allowed to drive, this group of students was chauffeured to wherever they went. Knowing directions is not the necessary skill to survival that it may be in other cultures. It would be interesting to track changes in this question group once students start routinely driving.

Students who passed the class demonstrated higher average scores in the majority of comparisons. For the overall spatial ability test score, passing students attained a mean score of two points (about 5%) higher than the failing students' mean. For each group, passing students typically scored slightly higher. As mentioned, many students do not complete the required PREP Math classes prior to entering Interior Design. Achievement in these classes also varies. Students who failed IDES I had a mean score of 59.71 in Introductory Algebra and 64.09 in Intermediate Algebra while students who passed IDES I carried an average of 74.66 and 73.23 in each math class. Moreover, failing students averaged over a third more attempts to pass Introductory Algebra than did passing students. Students who pass IDES I also tend to perform

much better in the other first semester freshman level IDES class: Freehand Sketching. Passing students averaged a grade of 86.05 and students who failed attained an average of 66.36 for Freehand Sketching. Of the twenty students who entered with previous art experience, nineteen of them are among the passing students.

4.2 Correlations-

Analyses of factors that influence student success over the entire course of their studies reveal elements that were not apparent with the initial first-year class assessment. Table 2 lists the significant elements. Non-significant influences were not included. Pearson bivariate two-tailed correlation was used for analysis.

Table 2: Correlations showing significant factors for student success

		IDES I	FREE-HAND SKETCHING	IDES II	DIGITAL I	IDES III	DIGITAL II	IDES IV	IDES V	IDES VI	IDES VII	IDES VIII
SPATIAL ABILITY TEST SCORE	Pearson	0.255	0.276	0.25	.137	.013	.061	-.093	-.020	-.028	-.063	.033
	Significance	.006	.006	.016	.216	.911	.596	.423	.857	.808	.583	.775
	N	115	97	92	83	83	79	77	80	76	78	78
INTRODUCTORY ALGEBRA	Pearson	0.351	0.316	0.447	0.455	0.363	0.389	0.33	.186	0.338	0.468	0.326
	Significance	.001	.005	.000	.000	.002	.001	.008	.136	.007	.000	.009
	N	91	78	73	68	68	65	63	66	63	64	64
INTER-MEDIATE ALGEBRA	Pearson	0.229	0.338	0.292	0.468	0.477	0.39	0.417	0.278	0.267	0.415	0.307
	Significance	.046	.005	.018	.000	.000	.002	.001	.030	.044	.001	.018
	N	76	69	65	63	63	60	57	61	57	59	59
GROUP 1	Pearson	.137	0.221	0.235	.093	.026	.108	-.012	.039	-.006	-.039	.064
	Significance	.146	.030	.024	.403	.819	.341	.918	.734	.959	.735	.578
	N	115	97	92	83	83	79	77	80	76	78	78
GROUP 3	Pearson	0.202	.150	.062	0.218	-.017	.009	-.164	-.128	-.124	-.062	-.030
	Significance	.031	.143	.556	.048	.879	.937	.154	.258	.286	.591	.796
	N	115	97	92	83	83	79	77	80	76	78	78
GROUP 4	Pearson	0.208	.147	0.233	.053	-.008	-.151	-.054	-.040	-.005	-.021	-.012
	Significance	.026	.151	.025	.633	.939	.183	.642	.722	.963	.856	.919
	N	115	97	92	83	83	79	77	80	76	78	78
FINITE MATH	Pearson	.148	.044	0.529	0.486	0.446	0.265	.202	0.323	0.33	0.347	.210
	Significance	.208	.716	.000	.000	.000	.023	.091	.005	.004	.003	.079
	N	74	71	60	56	70	73	71	73	73	73	71
CALCULUS FOR BUSINESS	Pearson	-.059	0.264	0.433	0.328	0.473	0.299	0.396	0.31	0.279	0.247	0.318
	Significance	.622	.027	.001	.013	.000	.011	.001	.008	.017	.035	.006
	N	73	70	59	57	70	72	71	73	73	73	72
INTRODUCTORY PHYSICS	Pearson	-.005	0.413	0.43	0.268	0.396	.207	.120	0.315	0.304	0.323	.200
	Significance	.965	.000	.000	.037	.000	.069	.299	.005	.007	.004	.083
	N	79	78	65	61	75	78	77	78	78	78	76

CRITICAL THINKING	Pearson	.116	0.231	0.36	0.418	0.449	0.431	0.46	0.256	0.378	0.352	0.349
	Significance	.254	.029	.001	.000	.000	.000	.000	.024	.001	.002	.002
	N	98	90	87	80	80	76	74	77	74	76	76

Correlation significant at the 0.01 level Correlation significant at the 0.05 level

Spatial ability is significant only for the first three classes. These studios involve heavy emphasis on technical and hand drawing. However, there is no or even inverse significance in the upper level studios. A few of the question groups demonstrated moderate correlation with a few studio classes. There is no obvious rationale for why these connections might exist.

IDES students are required to take Critical Thinking as part of their core classes in the second semester of their first year. Once students pass that class, it becomes a highly significant ($p \leq .002$, $\rho \approx 0.4$) indicator of studio success for all but two classes. Freehand Sketching is an elective class that students are encouraged to take during their first freshman class, but some students attend it later which would explain the influence of Critical Thinking for that class. Physics also shows correlation with performance in studios. Six classes are highly significant ($p \leq .007$, $\rho \approx 0.35$). Students are required to take this class in the first semester of the second year. There are no significant correlations between spatial ability scores and Critical Thinking or Introduction to Physics classes. However, there is strong correlation between students' Critical Thinking grades and Introduction to Physics grades ($p = .00$, $\rho = 0.413$).

All math classes demonstrated high correlations to many of the studio classes. Introductory Algebra was highly significant in all but one studio class ($p \leq .009$, $\rho \approx 0.38$). Intermediate Algebra has significant correlation to six studio classes ($p \leq .005$, $\rho \approx 0.42$). Finite Math taken as the first required core math class was also highly significant to six studio classes ($p \leq .005$, $\rho \approx 0.41$). Calculus for Business is the final required math class. It showed high significance for five studios ($p \leq .008$, $\rho \approx 0.39$) and significance to five others ($p \leq .035$, $\rho \approx 0.28$). There

are no significant correlations between spatial ability scores and any of the math classes.

V. ANALYSIS AND CONCLUSIONS

Spatial ability can predict success for students in early, technical type courses; however, it appears to be a weak assessment tool for upper level studios. Many of the studies on spatial ability only test beginning level classes and that may be why its importance is emphasized [14, 19, 21, 24]. The limited significance for spatial ability might be that female students typically score lower on spatial ability tests which constrains the effectiveness of these tests for women. Moreover, the type of spatial ability test chosen for this study could influence the lack of correlation. Further studies are currently ongoing employing the more commonly used PSVT:R to see if that particular test has more relevance. Where it might be valid for technical based classes, the lack of correlation to upper level design studios implies that more complex thought processes and problem solving are needed for student success.

Interior Design involves a continuous mix of design thinking, problem solving and critical evaluation of space, material performance, safety and psychology. This constant need for advanced thought processes is most likely why the Critical Thinking and Physics classes are highly correlated with success in IDES studios. Studies have found that students with a high level of critical thinking solve problems better and that students who hope to be successful in complex professions should be exposed to critical thinking methods early in their education [24, 25]. Students in Saudi Arabia are not

raised with the same level of critical thinking that is expected and inculcated into Western culture. To mold students and eventually graduates that stand apart from typical, PMU instituted critical thinking as one of its core competencies. All PMU students are educated on critical thinking methods early in their college career and this should continue especially for female IDES students as the data supports its highly positive influence on student studio success. Physics also had a high correlation with student studio performance. Very few, if any, PMU female students will have attended classes in physics prior to joining the university. Study of physics has been shown to improve spatial ability in students and research also shows that students with high spatial visualization abilities perform kinetic tasks better [26, 27]. The strong correlation between students' Critical Thinking grades and Introduction to Physics grades indicates that the thought processes for these topics are interrelated. Moreover, there is a link between the skills necessary to be successful in physics with those needed to perform well in design studios.

Success in mathematics classes also appears to correlate with success in studio classes at all levels. While some argue that spatial ability improves mathematics, others feel that early math classes improve design studio performance and yet, there is doubt as to what learning characteristics exactly link success in the two areas [28-31]. Nevertheless, this study shows that early intervention with math and requiring IDES students to attend continually more advanced math classes have a high correlation with studio class success at all levels.

This study, through following student performance over their entire college career, has shown that there is no one single factor that would predict success for new students entering a design program. It is a complicated mix of skills where some may exist naturally, but other, more important attributes may be nurtured and that would lead

students to success in the very complex profession of interior design. Further study is needed to determine if this result is applicable to male students and whether cultural factors influenced the results.

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