Taking an Engineering Spatial Visualization Course to Pre-Dental Students

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Olga Stavridis is a Senior Lecturer for the College of Engineering at The Ohio State University. She has been teaching Fundamentals for Engineering I and II for the Freshmen Engineering Scholars Program; Engineering Graphics and Spatial Visualization Courses for the last five years. She was previously the Director of the Engineering Co-op and Internship Program at Ohio State. Olga received her Bachelor's Degree in Industrial and Systems Engineering from Ohio State and Master's Degree in Industrial Engineering from Arizona State University. She has twelve years of industry experience in areas of Automotive and Systems Engineering.

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Dr. Lisa Abrams is currently the Associate Director for the Engineering Education Innovation Center at The Ohio State University (OSU). She received her Bachelor's and Master's Degrees in Mechanical Engineering and PhD degree in Industrial Engineering from Ohio State. She has seven years of industry experience in the areas of Design and Consulting. Her research focuses on the recruitment, retention, and success of undergraduate students, especially those populations who are under-represented in engineering. She has developed and taught a wide variety of engineering courses in First Year Engineering and Mechanical Engineering at Ohio State. She has received four teaching awards in the last three years at both the College and the Departmental level at OSU.

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Dr. Sheryl Sorby is currently a Professor of STEM Education at The Ohio State University and was recently a Fulbright Scholar at the Dublin Institute of Technology in Dublin, Ireland. She is a professor emerita of Mechanical Engineering-Engineering Mechanics at Michigan Technological University and the PI or coPI on more than $9M in grant funding, most for educational projects. She is the former Associate Dean for Academic Programs in the College of Engineering at Michigan Tech and she served at the National Science Foundataion as a Program Director in the Division of Undrgraduate Education from January 2007 through August 2009. Prior to her appointment as Associate Dean, Dr. Sorby served as chair of the Engineering Fundamentals Department at Michigan Tech. In this capacity, she was responsible for the development and delivery of the newly adopted First Year Engineering Program at Michigan Tech. She received a BS in Civil Engineering, an MS in Engineering Mechanics, and a PhD in Mechanical Engineering-Engineering Mechanics, all from Michigan Tech. Dr. Sorby has a well-established research program in spatial visualization and is actively involved in the development of various educational programs.

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Dr. Hamamoto has authored/co-authored publications in the areas of the acid-evoked pain, cancer-evoked pain, antihyperalgesic effects of cannabinoids, and glycemic control in diabetic dental patients. He has mentored minority high school, undergraduate, graduate and dental students and dental specialty residents in both basic science and clinical research. Dr. Hamamoto has been awarded UMN Graduate School grants, a National Institutes of Health (NIH) grant, and is or has been Co-investigator on five other NIH grants. Dr. Hamamoto serves as an ad hoc reviewer for national and international basic science and dental journals, including the Journal of Dental Education.

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Ken Sigler is the Director of DentPath and Associate Director of Admissions in the College of Dentistry at The Ohio State University. He is responsible for the recruitment of underrepresented minorities as well as pipeline programs serving middle and high school students in underserved areas. He has over fifteen years of experience in higher education administration spanning from student affairs to enrollment management. Prior to his current role in the College of Dentistry, he served as the Director for Undergraduate Admissions at Ohio State Mansfield. He was also Director of Admissions at Brevard College in Brevard, North Carolina. Ken earned his Bachelor's degree in Communication at Muskingum University and his Master's in Higher Education Administration at Kent State University. He completed his Ed.D. in Higher Education Leadership at Azusa Pacific University in Azusa, CA.

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Abstract

This paper describes an active research study examining the effectiveness of a spatial visualization course offered by the College of Engineering at The Ohio State University for students who desire to enroll in dental school. Students who enroll in the spatial visualization course are either first year engineering students, undergraduate students who are majoring in a pre-dental curriculum anticipating taking the Dental Admissions Test (DAT), or students who are in a post baccalaureate program (PostBac) that conditionally accepts them into dental school. The DAT includes a "Perceptual Ability Test" (PAT) section that is a test of spatial visualization and there is evidence that the PAT predicts performance in pre-clinical dental school courses. This paper will evaluate the impact of the course on the Purdue Spatial Visualization Test: Rotations (PSVT:R), the potential correlation between the PSVT:R and the PAT, and the performance of the PostBac students in the future dental school key courses that heavily rely on strong perceptual abilities.

The PostBac Program

The PostBac students are enrolled in a specialized program called PostBac. The PostBac Program at The Ohio State University is a one-year post-baccalaureate program that helps students become more competitive and successful in the dental school environment. The goal of the program is to increase the number of students in dentistry who are from underrepresented groups and/or from economically or educationally disadvantaged backgrounds. The program consists of a one-week orientation that includes learning strategies, community service projects, and seminars. The academic year includes 30 hours of science-intensive coursework over two semesters, to help prepare students for the rigors of dental school. In addition, beginning in the fall of 2014, PostBac students are also required to successfully complete a one-credit hour spatial skills course. Students who successfully complete the PostBac program are automatically accepted to the dental school program at The Ohio State University.

To be eligible for the program, students must first submit their application to the dental school at The Ohio State University. Typically PostBac students are quality students with a high probability to serve underserved patients, but did not have as competitive undergraduate GPAs as the rest of the applicant pool. One hundred and ten students are admitted to Dental School and 7-9 of those students are typically admitted to the Post Bac program.

Traditionally admitted students in the AU 14 dental school program had an average PAT score of 20.62 while the PostBac cohort had an average PAT score of 18.43.

Dental Aptitude Test

The Dental Aptitude Test (DAT; ADA, 2000), a standardized exam through the American Dental Association, is taken at a secure testing site using a computer and consists of problems in five academic areas including Quantitative Reasoning, Reading Comprehension, Biology, General Chemistry, and Organic Chemistry. A sixth component of

the test, called the Perceptual Ability Test (PAT), is a test of spatial visualization skills that is largely unrelated to the subjects studied by the typical pre-dental student. The PAT consists of 90 items, 15 from each of six types on the test. The time allotted for the entire 90-item test is only 60 minutes meaning that the students must be able to answer the problems correctly and quickly if they are to score well on the PAT. The types of problems found on the PAT are described in the following sections. Students enrolled in the PostBac program scored at least ~60% on the PAT portion of the DAT.

The first type of problem on the PAT is called "Keyhole" problem. For keyhole problems, the students are presented with a 2-dimensional drawing of a 3-dimensional object on the left and they must mentally rotate the object to try to fit it through one of five diagrams of an aperture. For Keyhole problems, once the object starts through the aperture, it cannot be turned in space. Figure 1 shows a sample problem from the keyhole portion of the test.

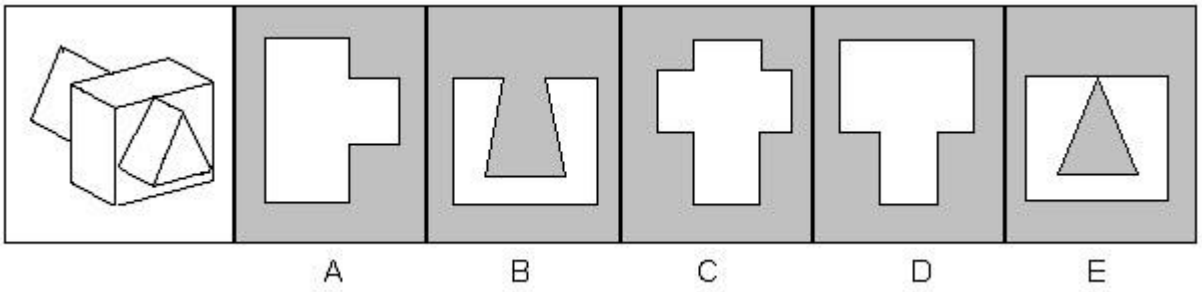

Figure 1. Keyhole problems from the PAT (Correct answer is A)

The second type of problem on the PAT is called the Top/Front/End problem. These problems are essentially missing view problems where students are presented with two views of an object, e.g., the top and front views, and they must choose the missing view from the choices given. Figure 2 shows an example problem from the Top/Front/End portion of the PAT.

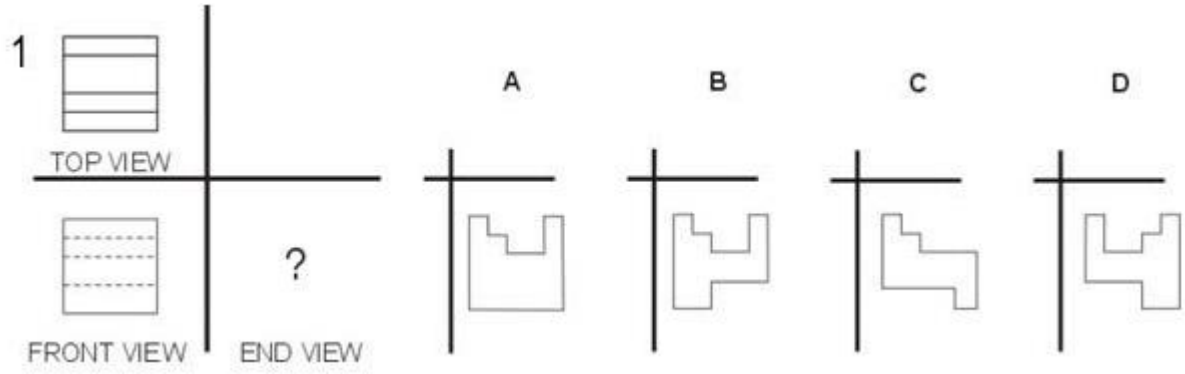

Figure 2. Top/Front/End problems from the PAT (Correct answer is B)

The third type of problem from the PAT is a perceptual type of problem where students must determine the relative sizes of angles created by pairs of lines and select the correct order from smallest to largest. Figure 3 shows an example of this type of problem from the PAT.

Figure 3. Perceptual Angles problems from the PAT (Correct answer is 3-2-1-4)

The next type of problem on the PAT is a standard paper-folding task found on several tests of spatial cognition. For this type of problem, students are presented with diagrams of a piece of paper that is folded in subsequent operations. A hole is then punched through the folded paper and students are instructed to mentally unfold it and select what it would look like from the choices given. Figure 4 shows an example of the paper folding problems on the PAT.

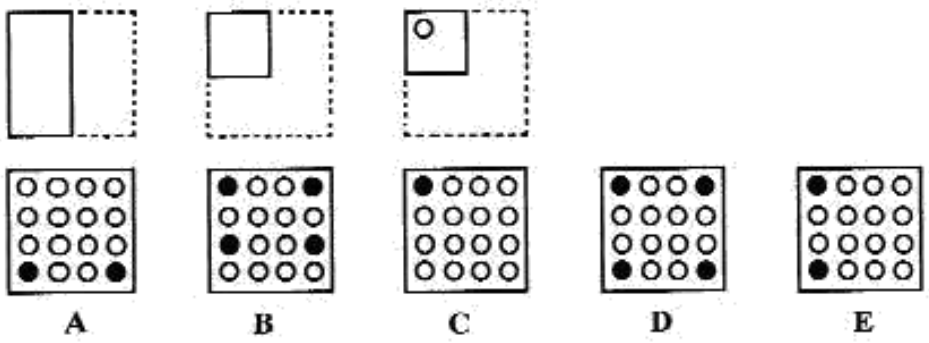

Figure 4. Paper folding problems from the PAT (Correct answer is D)

For the fifth set of problems, students are presented with a diagram of a figure made from several blocks. They are instructed that the exposed sides of the blocks have been painted, but the unexposed sides and the sides on the bottom of the figure have not been painted. They are then asked various questions about the number of blocks with a given number of sides that have been painted, e.g., how many blocks have three sides painted? A sample problem from this type of problem is shown in Figure 5. The student is asked how many cubes have two of their exposed sides painted?

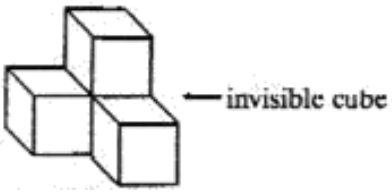

Figure 5. Painted surfaces problems from the PAT (Correct answer is 1 cube)

The final type of problem from the PAT is a paper folding task similar to those found on the Differential Aptitude Test: Space Relations[1]. With this type of problem, students are presented with a diagram of a flat pattern and instructed to imagine folding it to form a 3-D object. Figure 6 shows an example problem from this portion of the test.

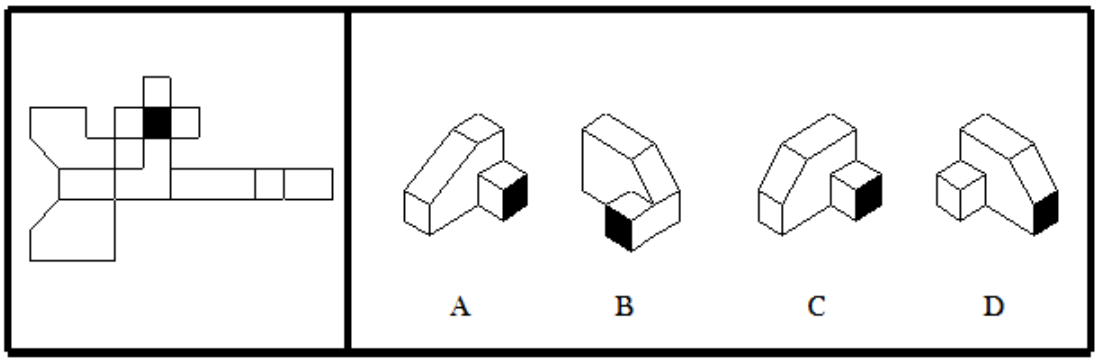

Figure 6. 2-D to 3-D paper folding problems from the PAT (Correct answer is C)

Dental school curricula typically consist of academic portions (e.g., advanced science courses) as well as dental techniques portions. The dental techniques portions of the program are divided into a pre-clinical and clinical. The difference between these two portions is that the pre-clinical courses are those where students learn to do things like prepare a crown in an idealized simulation setting whereas in the clinical portions, they actually prepare a crown on a living person. Pre- clinical grades are an assessment of skills or techniques; whereas, clinical grades will typically include things such as clinical decision making, time management, and interpersonal skills as well as techniques.

In studies of the predictive strength of the DAT for success in dental school, some interesting observations have been found[2-5]:

- The academic portions of the DAT (biology, chemistry, etc.) are predictors of grades in the academic portions of the dental program.
- The academic portions of the DAT are not predictors of success in either the pre-clinical or the clinical portions of the dental program.
- The PAT (spatial skills portion) scores are not predictors of grades in the academic portions of the dental program.
- The PAT scores are predictive of pre-clinical grades, but not of clinical grades.

A study of the correlation between scores on the PAT and the widely-used Purdue Spatial Visualization Test: Rotations (PSVT:R)[6] was conducted with pre-dental students at The Ohio State University and correlations between student scores on the two tests were investigated. For this test, the students were given a test that consisted of the odd-numbered problems from the PAT meaning that the scores were out of 45 possible points instead of 90 points. The rationale for this was that the amount of time for the entire PAT (60 minutes) was considered to be too long for classroom implementation. By selecting every other problem, it is likely that the problems given were of varying difficulty as the actual test questions are on-line and randomized. Figure 7 shows the data from this analysis.

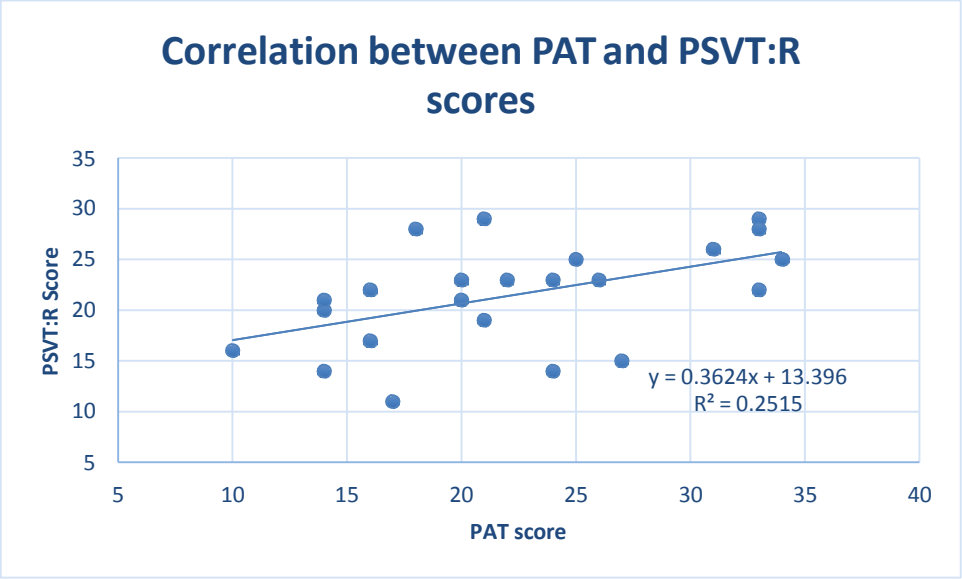

Figure 7. Correlation between PAT and PSVT:R test scores

As it can be seen from the data presented in Figure 7, the correlation coefficient shows there is a moderately strong correlation between a student's performance on the PAT and his/her performance on the PSVT:R. The correlation coefficient (r=0.5015) is statistically significant (p=0.0148). The p value was calculated using the t test for the significance of the correlation coefficient

Spatial Skills Course for PostBac

Beginning in the Autumn 2014, PostBac students were required to take the one-credit hour spatial skills course offered at The Ohio State University that was initially aimed at helping first-year engineering students improve their spatial visualization skills and better prepare them for the Fundamentals of Engineering Course. Beginning in Autumn 2012, the PostBac students were encouraged to enroll in this optional course but were not required to do so. During the summer orientation for incoming engineering freshmen students, they are administered the Purdue Spatial Visualization Test: Rotations (PSVT:R) online assessment. If engineering students score below 18/30, they are strongly recommended by their advisor to enroll in the course.

This 80 minute class met once a week and utilized the Developing Spatial Thinking Workbook[7]. The maximum capacity of student enrollment for each of the sections was 36. Four students sat at each table and each student had use of a computer. A Tactile Modeling Set (linking cubes) were provided to students to build the objects based on given coded plans detailed in the workbook. During each class, a new module was introduced during a brief lecture and then class continued with the following:

Class Structure:

Class Structure:	Time:
A. Instructor led lecture and demonstration (done using a document camera)	15 – 20 minutes
B. In class exercise completed as a team at each table	10 minutes
C. Computer module completion	15 minutes
D. Open lab time to work on all homework problems.	35-40 minutes

Attendance was required for the one-credit hour class that was graded Satisfactory/Unsatisfactory (70% was the cutoff in the grading scheme).At the end of week 10 when all modules have been completed, the PVST:R was administered again for students to gauge their before/after scores. Table 1 includes the pre-/post-test data for PostBac students from the Autumn 2013 and 2014 semesters. The data presented in this table indicates that the students improved their spatial skills as measured by the PSVT:R by a significant amount as a result of the t-test matched pairs.

Table 1. Average PSVT:R Test Scores for PostBac Students

	Pre-Test	Post-Test
PostBac students from AU '13 & '14 (n=15)	19	23
Standard Deviation	4.123	3.222
Significance of gain	p=0.0033	

Pre Clinical Exam Grades for PostBac

Of the Pre Clinical courses, Operative Dentistry I is one that relies heavily on strong perceptual abilities. There are three practical ("hands on") exams during the Operative Dentistry I course. Part of each examination requires dental students to prepare ("drill a cavity") on a plastic tooth. The type of preparation becomes more difficult from exam to exam. Preparations are scored from 0 to 4 with 2 being passing. Scores can be whole and half numbers, e.g. 2.0 or 2.5 but not 2.25. Three instructors evaluate each preparation independently and the score for each student is calculated using the median. If there is disagreement among the instructors by more than 0.5 points, the two course directors re-evaluate the preparation and assign the final score. Table 2 shows the average grades for

each examination for dental school students (not PostBac) vs PostBac Students. Based on the results of the t-test, there is no statistical difference between Dental (not PostBac) students and PostBac students based on the p-value using an alpha error = .05.

Table 2. Average Pre-Clinical Exam Grades for Dental School Students

	Practical 1	**Practical 2**	**Practical 3**	**Average**	**Stdev**	**Median**
Dental School students (PostBac not included)	2.37	2.24	2.13	2.25	0.34	2.23
PostBac students	2.49	2.00	2.21	2.23	0.36	2.29
Significance	Not significant at 5%	Not significant at 5%	Not significant at 5%	Not significant at 5%		

We will track dental school graduation rates of the PostBac program students. Furthermore, we intend to investigate the differences in gender and corresponding scores.

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