AC 2010-617: ARE THE VISUALIZATION SKILLS OF FIRST-YEAR ENGINEERING STUDENTS CHANGING?

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Abstract

Michigan Tech has been offering a course in the development of 3-D spatial skills since 1993. Each year since that time, engineering students have been tested with a standardized instrument during orientation and those who failed have been counseled to enroll in the spatial skills course. Instruments regarding student background experience have also been periodically administered. In this study, historical data was examined to determine if there were changes in test results through the years. The items of interest in this study were: changes in the average score on the spatial skills instrument through time, changes in failure rates on the pre-test, the impact of computer games on spatial skills development, gender differences in scores and failure rates through time, and changes in background variables through time. Data trends in this study will inform us regarding changing student backgrounds and will indicate whether the need for a spatial skills intervention course is increasing or decreasing.

Background

Spatial skills have been shown to be important to success in many technical fields and have been found to be particularly important to success in engineering graphics. In a study conducted by Gimmestad[1], a student's score on the Purdue Spatial Visualization Test: Rotations (PSVT:R) was shown to be the most significant predictor of success of eleven variables tested. In this study, PSVT:R pre-test scores and other variables of interest were correlated with final scores in an engineering graphics course. Variables that were not correlated with success in engineering graphics included component scores on the ACT (math, verbal, science, and composite). When the variable of play with construction toys was combined with the variable of previous experience in drafting or shop courses, a marginally significant factor was obtained.

In various studies conducted through the years, many background factors have been shown to be correlated with well-developed spatial ability. Although each study has produced slightly different results, it seems that activities that require eye-to-hand coordination are those that help to develop these skills. Activities that have been found to develop spatial skills include: 1) playing with construction toys as a young child, 2) participating in classes such as shop, drafting, or mechanics as a middle school or secondary student, 3) playing 3-dimensional computer games, 4) participating in some types of sports, and 5) having well-developed mathematical skills.

In recent studies, the role of computer games, particularly those with 3-D simulations, have been examined for their impact on the development of spatial skills. Terlecki and Newcombe[2] conducted a study with students enrolled in an undergraduate psychology course. They administered a Survey of Spatial Representation and Activities (SRRA) to 1300 students of diverse ethnicities and majors (engineering students made up less that 1% of those tested). Those students who scored high on the SRRA, signifying that they had a high level of engagement in computer use and video game playing, and those who had a low score on the SRRA were invited to take the Mental Rotation Test[3] (MRT). It was found that there was a high degree of gender difference in SRRA scores, with women less likely to have computer/video game experience than men. It was also found that students with high scores on the SRRA scored significantly higher on the MRT than those with low scores on the SRRA and this difference was higher than the gender difference.

In a follow-up project, Terlecki, Newcombe, and Little[4] conducted a study with college-age students using 3-D Tetris as a spatial skills training aid. In this study, students in one experimental group were asked to play Tetris at least one hour per week over a 12-week period; students in the comparison group were asked to play Solitaire one hour per week over the same period. It was found that the video game “training” with Tetris improved spatial skills on a variety spatial tasks when compared to those who did not play Tetris.

In research conducted by Sorby et al[5], it was found that students who completed spatial skills training through multimedia software alone did not improve their spatial skills by a significant amount over those in a comparison group that was not exposed to the software. However, Achtman, Green, and Bavelier[6] found that in order to improve spatial skills through video game play, *action* games were required. It could be that the software developed by Sorby and Wysocki[7] was too passive for effective spatial skills development when compared to other software-based training materials such as action video games.

Since its introduction in the early 1980s, the personal computer has changed American life. The PC has changed the way we communicate with one another, the way we obtain information, and the way we are entertained. The development of video games and video game systems has been particularly explosive; in 2000, 89% of American homes with children had a personal computer or other video-game capable equipment[8]. However, the majority of the games that have been introduced have been designed with young men in mind. Boys spend more time than girls playing video games[9,10], and the difference increases with age[9]. Some speculate that this will result in a widening of the spatial skills gap between young men and young women in the future. Michigan Tech has been conducting spatial skills testing with incoming engineering students since 1993. In this paper, the results from spatial skills testing since 1996 are presented to determine any trends in the data, especially with respect to the impact of video game play on spatial skills development.

Spatial Skills Testing at Michigan Tech

In 1993, the PSVT:R was administered to 535 first-year Michigan Tech engineering students during orientation. Students who were tested had declared a major of civil, environmental, mechanical, materials, mining or general engineering. At the time, these were the only engineering majors that still had a graphics requirement. Of the 96 students who failed the test with a score of 60% or less, 43% were women, even though women were only 17% of the group taking the test. Thus, the women were almost three times more likely to fail the test than were their male counterparts. Furthermore, of the 45 students who earned a perfect score on the test, only 3 were women. Gender differences between failure and success rates on the test were statistically significant.

Since 1993, engineering students at Michigan Tech have continued to be tested with the PSVT:R during orientation. From 1993 through 1999, only the students enrolled in majors requiring graphics (civil, environmental, materials, mechanical, mining, and general engineering) were tested; beginning in 2000, with the implementation of a common first-year engineering program at Michigan Tech, all first-year engineering students have been tested. Recently, data from the testing was located for 1996-2009 and examined for longitudinal differences in PSVT:R performance. [Data for 1993-1995 could not be found.] The results from this longitudinal analysis follow.

Average Test Scores

Figure 1 shows the PSVT:R average test scores between 1996 and 2009 for all students tested. From this data, it appears that the average pre-test score for engineering students has been relatively constant over the past 14 years, with a slight trend upwards over time.

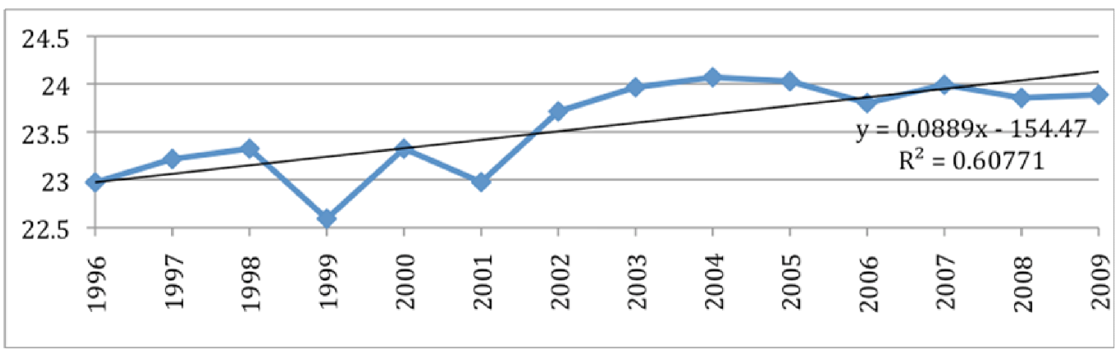

Figure 1. Average PSVT:R Scores Over Time

Figures 2 and 3 show this same data disaggregated by gender. From this data, it appears that any upward trend in the overall data is likely due to an increase in the average test score for women. The male test results exhibit the same, relatively small (slope=0.0613), trend as shown in the overall data while the female test results indicate a stronger upwards trend over time (slope=0.1545). Since females are only ~20% (or less) of the students taking the test, their improvement over time is not readily apparent from the overall data presented in Figure 1.

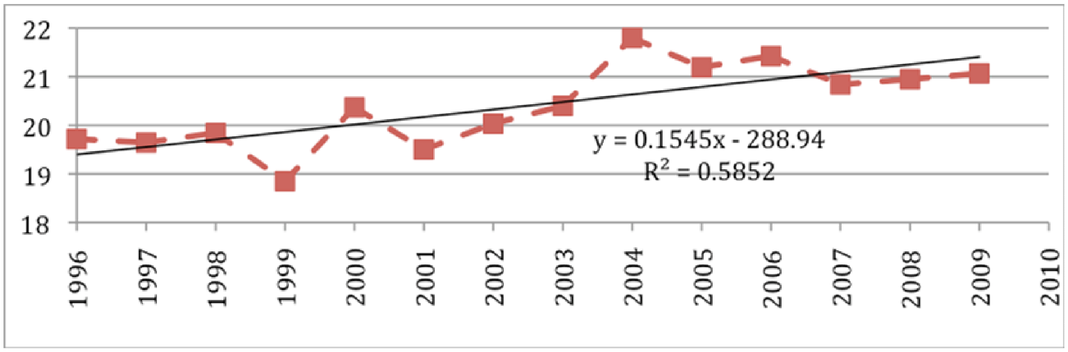

Figure 2. Average PSVT:R Scores for Females Over Time

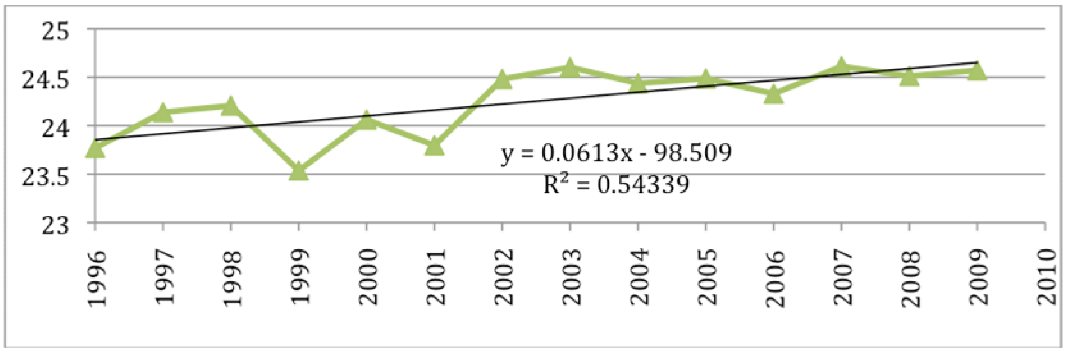

Figure 3. Average PSVT:R Scores for Males Over Time

Failure Rates

Performance on the PSVT:R has been linked to success in graphics and to success in Michigan Tech's first-year engineering courses. Students who fail the PSVT:R during orientation are counseled into a special spatial skills course to help them improve their spatial cognition. [Beginning in 2009, students who fail the PSVT:R are now *required* to take the spatial skills course.] Figure 4 shows the failure rates for the PSVT:R from 1996 through 2009. The slight downward trend in failure rates on the PSVT:R is encouraging and could be somewhat influenced by the rapid expansion of action video games over the same timeframe.

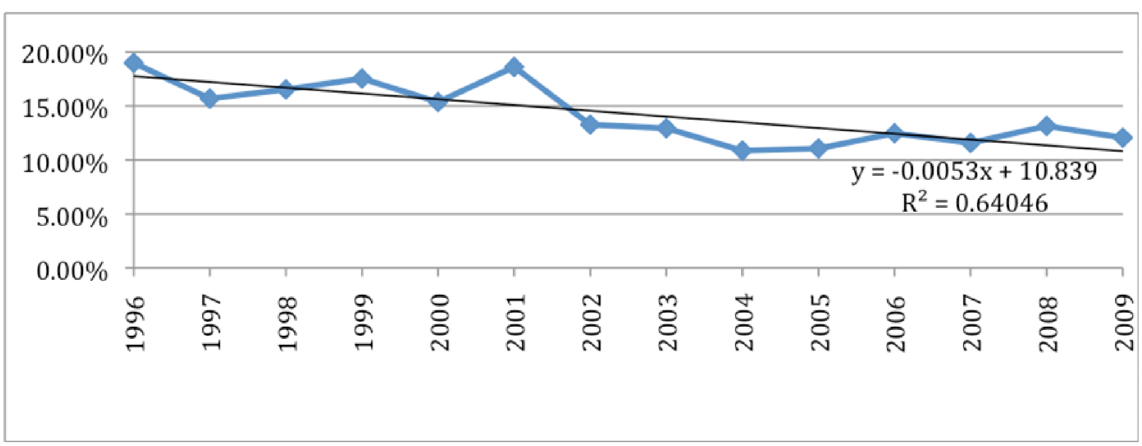

Figure 4. Failure Rates on PSVT:R Over Time

Figures 5 and 6 show the data from Figure 4 disaggregated by gender. In this figure, a slight downward trend in failure rates for men mirrors the trend shown in the overall data; however, the female failure rate trends significantly downward over the thirteen-year period. Once again, the improved performance of women is masked in the overall data (Figure 4) due to their low representation in the population being tested.

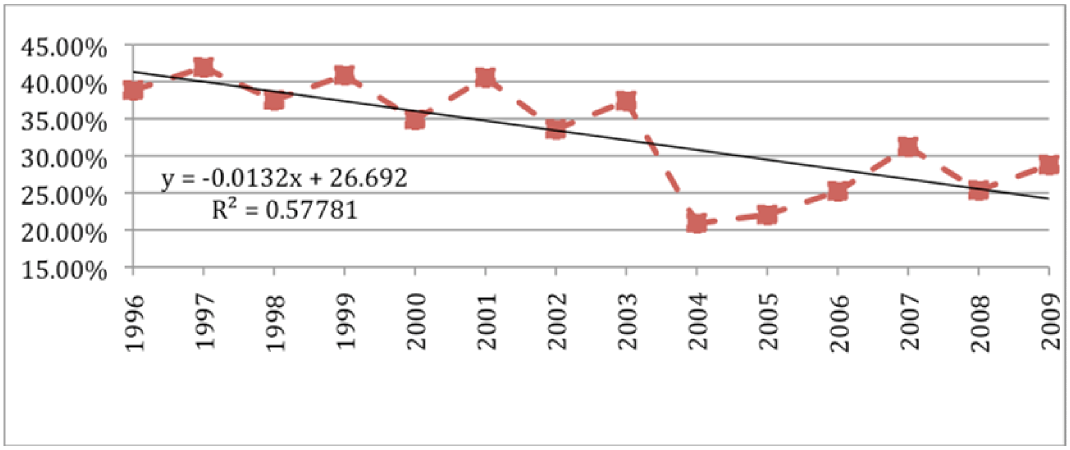

Figure 5. Failure Rates on PSVT:R for Women Over Time

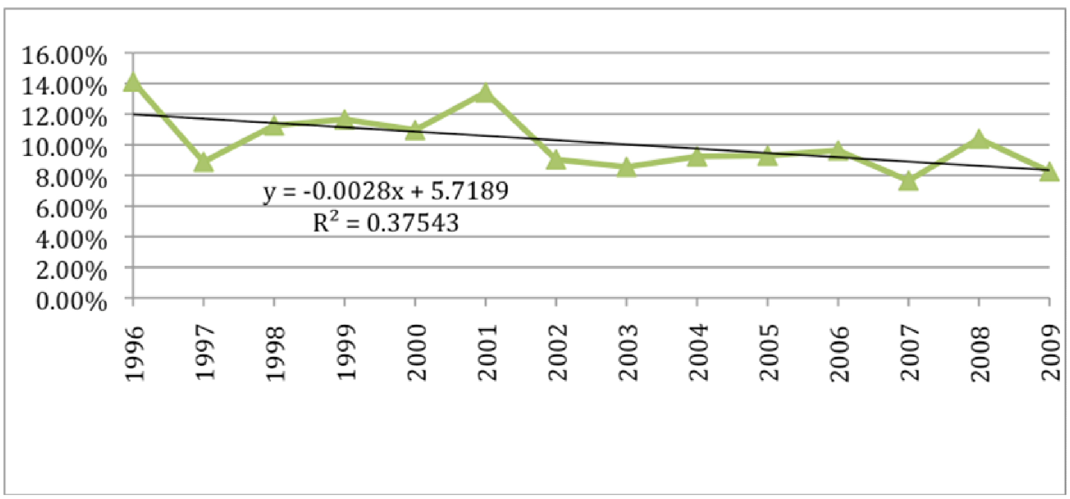

Figure 6. Failure Rates on PSVT:R for Men Over Time

The significant "dip" in failure rate data for women in the year 2004 may be explained somewhat by enrollment data. Figure 7 shows the number of women taking the PSVT:R during orientation from 2000 through 2009. Recall that prior to 2000, only students in selected majors took the PSVT:R during orientation. From the data presented in Figure 7, it is clear that the dip in failure rates corresponded with a low point in female engineering enrollment at Michigan Tech. It could be that in 2004, the females who enrolled in our engineering programs were more dedicated and better prepared for engineering than in prior or subsequent years. Enrollment for male students was stable over the same time period.

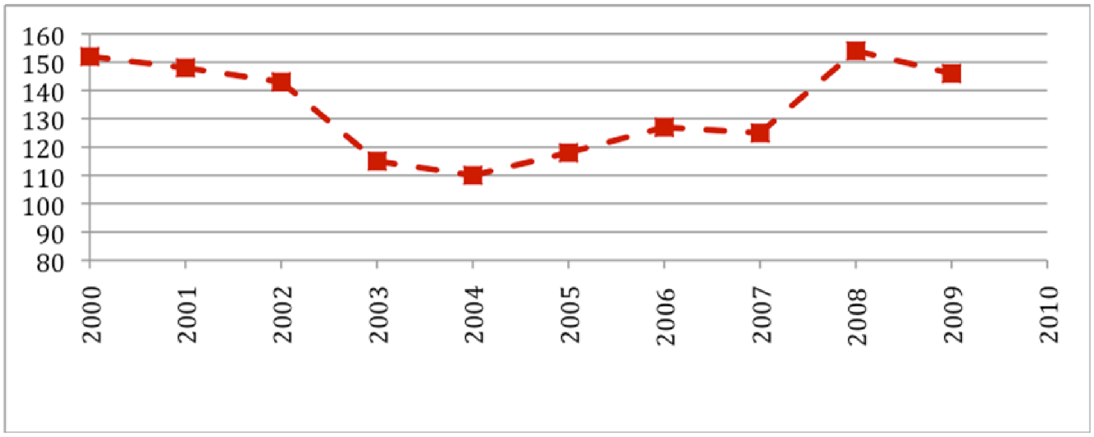

Figure 7. Enrollment for Women Over Time

Perfect Scores on the PSVT:R

Figure 8 shows the percentage of students overall who got a perfect score of "30" on the PSVT:R during orientation by gender. From the data presented in this figure, it appears that the percentage of students who earned a perfect score has remained relatively constant over time, with no trend either upward or downwards and there are no clear trends by gender.

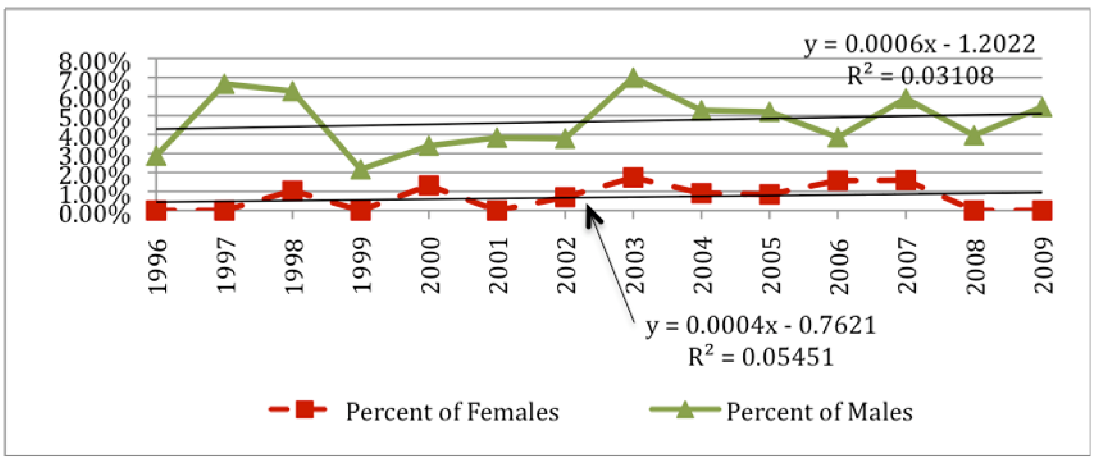

Figure 8. Percent of Students with a Perfect Score on the PSVT:R by Gender

Gender Differences in PSVT:R Test Results

The data presented in the previous figures shows gender differences in PSVT:R scores over time for average score, failure rates, and perfect scores. The gender differences in each case favors males. But are these gender differences statistically significant? In performing a z-test and t-test on the differences between failure rates and average test scores, respectively, significant gender differences were found for each of the fourteen years of data ($p<0.0001$ in each case). Table 1 presents the percent of students by gender with a perfect score on the PSVT:R and the level of statistical significance of the difference between the proportions for each. From this analysis, it is apparent that significant gender differences remain, despite improvement in female performance on the PSVT:R over time.

Table 1: Percent of Students with a Perfect PSVT:R Score by Gender

Year	Percent of Males	Percent of Females	Statistical Significance of Difference in Percentages
1996	2.88%	0.00%	p=0.119
1997	6.67%	0.00%	p=0.011
1998	6.28%	1.04%	p=0.036
1999	2.17%	0.00%	p=0.161
2000	3.41%	1.32%	p=0.136
2001	3.83%	0.00%	p=0.016
2002	3.79%	0.70%	p=0.051
2003	7.00%	1.74%	p=0.026
2004	5.28%	0.91%	p=0.038
2005	5.19%	0.85%	p=0.032
2006	3.85%	1.57%	p=0.157
2007	5.90%	1.60%	p=0.039
2008	3.95%	0.00%	p=0.012
2009	5.45%	0.00%	p=0.004

Impact of Computer Video Games over Time

Background questionnaires have been periodically distributed to students in research studies in which Sorby has participated since 1993. A comprehensive background questionnaire was also completed by students in the fall 2009 cohort. Although data is not available for each year examined in this paper, the years for which prior data exists provide a snapshot of the impact of playing computer video games over time.

In 1993, the following question was asked of students taking the PSVT:R, "Did you play video/computer games as a child or teenager?" Response choices (number of responses) were: Never (20), Every few months (155), Monthly (92), Weekly (174), and Daily (94). When responses to this question were analyzed using multiple regression analysis, playing computer video games was not a significant predictor for a student's score on the PSVT:R (p=0.3326).

In 1998, Sorby participated in a study conducted with colleagues from Germany and Poland[11]. During this study, background questionnaires were administered to first-year engineering students at the University of Kaiserslautern (UKL) and the Cracow University of Technology (CUT) along with various tests of spatial ability. In this test, it was found that playing with video games was a significant background predictor for performance on a test of mental rotation for students at UKL (p=0.0003) but not for students at CUT. At UKL a significant gender difference in playing computer games was also found.

In 2004, Sorby conducted a study with non-engineering students. These students, primarily from computer science and biology, were administered the PSVT:R and a background questionnaire, similar to studies conducted previously with engineering students. For this study, statistically significant differences in scores on the PSVT:R were obtained for students who regularly played video games compared to those who did not ($p<0.01$) and males reported playing video games at greater frequency compared to females (84.6% vs. 25%). The gender difference in video game play was statistically significant.

On the background questionnaire administered along with the PSVT:R during fall 2009, three questions were included related to video game playing. These questions and their response choices are included below. For each question, response choices were a) many hours per week , b) once or twice per week , c) once or twice per month , d) once or twice per year, or e) never .

Instructions: For each activity listed below, fill-in the appropriate bubble on the Scantron sheet that indicates the most amount of time that you spent on that activity during any given year in your life.

> 6. Played computer or video games (such as action, adventure, racing, or sports games)
> 20. Spent time solving 3-D puzzles or playing 3-D computer games like 3-D Tetris or Blokus
> 22. Joined on-line fantasy games that involve navigating through a 3-D environment such as Myst, Tomb Raiders, or World of Warcraft

Tables 2-4 present the results from the analysis of the data by gender regarding computer video game usage obtained from the background instrument. In each case, it appears that video game usage is significantly correlated with PSVT:R test score. Gender differences in video game play were statistically significant ($p<0.0001$ for Q6 and Q22, $p=0.0021$ for Q20). This data also suggests that video game play is more important for females than it is for males in the development of 3-D spatial skills.

Table 2: Comparison of PSVT:R scores and time spent playing computer or video games

	Males n=576	Females n=140
Average time spent on activity	4.09[1]	3.06[1]
Correlation of time spent on activity with PSVT:R score	0.113 p=0.0034	0.229 p=0.0033
Average PSVT:R score of those that spent some time doing activity	24.61 n=565	21.57 n=122
Average PSVT:R score of those never doing activity	23.91 n=11	18.94 n=18
Statistical significance of difference in PSVT:R scores of those doing and those not doing activity	p=0.276 (NS)	p=0.0113

[1]A rating of 3 = did activity once or twice per month, a rating of 4 = did activity once or twice per week

Table 3: Comparison of PSVT:R scores and time spent solving 3-D puzzles or playing 3-D computer games

	Males n=574	Females n=140
Average time spent on activity	2.60[1]	2.29[1]
Correlation of time spent on activity with PSVT:R score	0.141 p=0.0004	0.312 p<0.0001
Average PSVT:R score of those that spent some time doing activity	24.77 n=468	22.33 n=97
Average PSVT:R score of those never doing activity	24.00 n=105	18.77 n=43
Statistical significance of difference in PSVT:R scores of those doing and those not doing activity	p=0.035	p<0.0001

[1]A rating of a rating of 2 = did activity once or twice per year, 3 = did activity once or twice per month

Table 4: Comparison of PSVT:R scores and time spent playing on-line fantasy games that navigate through a 3-D environment

	Males n=575	Females n=140
Average time spent on activity	2.16[1]	1.42[1]
Correlation of time spent on activity with PSVT:R score	0.107 p=0.005	0.204 p=0.0078
Average PSVT:R score of those that spent some time doing activity	25.16 n=250	23.8 n=25
Average PSVT:R score of those never doing activity	24.22 n=325	20.68 n=115
Statistical significance of difference in PSVT:R scores of those doing and those not doing activity	p=0.0019	p=0.0009

[1]A rating of a rating of 1 = never did activity, 2 = did activity once or twice per year

Conclusions

In examining the results from spatial skills testing over the past 14 years, some encouraging results have been obtained. It appears that the spatial skills of incoming engineering students have been increasing through time, particularly for young women. Not only is the average PSVT:R test score increasing for young women, but their failure rate is decreasing; however, significant gender differences still remain.

Evidence suggests that the significance of video game play in developing 3-D spatial skills is increasing over time, likely due to changes in the sophistication and quality of the 3-D representations in games over the past decade. It appears that improvements in spatial skills could be the result of the wide availability of 3-D computer video games and students' increased play with these games. Playing with computer video games appears to be particularly important for women compared to men in developing 3-D spatial skills and that some play (as infrequent as 1 to 2 times per year as a child) is better than no play. "Students aren't what they used to be" is a common lament among engineering educators. In terms of 3-D spatial skills for incoming students, it appears that this might be true and that students, in fact, may be *better* than they used to be.

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