# Gender Differences in Spatial Visualization Among Rural and Urban Populations

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***Abstract***

*Women are underrepresented in STEM despite ongoing work. One area that might be a factor in the underrepresentation of women in engineering is large gender difference in spatial skills. The purpose of the research presented here was to explore if gender differences exist between rural and urban middle school students. Well established spatial visualization tests were used to collect data that was then analyzed using an ANOVA. Findings suggest that some differences do exist.*

**Background**

Women continue to be underrepresented in most engineering disciplines. Achieving equal representation is not only important for social justice reasons but also in addressing the grand challenges of the future. One factor that is likely to contribute to women being unsuccessful in engineering programs pertains to their spatial skills. Spatial skills of females continue to lag behind their male counterparts, a key aspect of engineering education (e.g. Leopold, Sorby, & Gorska, 1996; Linn & Petersen, 1985; Medina, Gerson, & Sorby, 1998; Sorby, 2009; Sorby, Casey, Veurink, & Dulaney, 2013; Veurink & Sorby, 2011; Wei, Chen, & Zhou, 2016). Spatial skills refers to the ability to conceptualize real and imagined spatial relationships including being able to mentally manipulate, organize, and reason about these relationships. Spatial skills have been found to relate to gender equity within a country – countries where women are treated more equitable have better spatial abilities compared to countries where women are treated less equitably (Lippa, Collaer, & Peters, 2010). Additionally, spatial skills have been found to differ across socioeconomic (SES) groups, with significantly lower spatial skills found among low SES groups compared to students from high SES groups (Levine, Vasilyeva, Lourenco, Newcombe, & Huttenlocher, 2005).

Most studies have focused on urban populations when studying the spatial skills of students from different groups (SES status, gender etc.) but few have compared differences between students in rural and urban populations. Rural populations are unique in the sense that they are often of lower SES status but they also may have greater opportunities to develop spatial skills through their environment (outdoor play, stay-at-home parent, etc) compared to their urban counterparts. Students from rural areas are 32.2% less likely to pursue post-secondary education compared to non-rural youth (Byun, Meece, & Irvin, 2010). By understanding the spatial skills of rural youth, targeted STEM interventions can be adapted with these findings in mind to help attract more rural youth to post-secondary STEM degrees.

**Purpose**

The purpose of this research is to examine if differences exist between males and females from rural and urban locations in their spatial skills. Due to environmental factors, we hypothesize that both male and female students from rural locations will perform statistically significantly higher on spatial tests compared to their counterparts in urban locations.

**Methods**

The data used in the analysis presented here was collected in 18 middle schools from seven states (Texas, Michigan, Georgia, Colorado, Ohio, Tennessee, and Alabama) in rural and urban areas within the United States. To be considered rural, the school had to be located in an area with a population of less than 50,000 residents. A majority of the students were of white/non-Hispanic race/ethnicity.

A total of four tests of ten problems each were administered. The tests used here have been shown to be valid for people as young as 7$^{th}$ grade (Hungwe, Sorby, Molzan, Charlesworth, & Wang, 2014). These tests are widely known in the engineering graphics education community and are:

- Purdue Spatial Visualization Test: Visualization of Rotation (PSVT:R) (Guay, 1977).
- Differential Aptitude Test: Space Relations (DAT:SR) (Bennett, Seashore, & Wesman, 1973).
- Mental Cutting Task (MCT) (CEEB, 1939).
- Modified Lappan Test (LAP) (Lappan, 1981).

Data collection occurred sometime in the second semester (~March of 2016 and 2017) of grade 7. Testing was spread out over at least two class periods by the math or science teacher at each respective school.

Responses were analysed using IBM SPSS where both descriptive statistics and an ANOVA was used to test the differences between genders in urban and rural locations relative to their performance on the spatial skills tests. The sample size varied as shown in Table 1.

**Table 1. Sample size for each of the four groups and across the four tests**

| | DAT | PSVT | LAP | MCT |
|---|---|---|---|---|
| Rural Male | 766 | 766 | 714 | 710 |
| Rural Female | 694 | 694 | 648 | 640 |
| Urban Male | 636 | 624 | 328 | 314 |
| Urban Female | 636 | 624 | 291 | 287 |

**Results**

Means obtained in this analysis are presented in Table 2 and explained in the following sections. Letter superscripts in Table 2 indicate where statistically significant differences were found. For example, if superscripts are the same, then no statistical differences were found between these two groups. Likewise, if superscripts are different, a statistical difference is present.

For the DAT:SR, differences were statistically significant between Male Rural, Male Urban, and Female Urban, with Male Rural students scoring the highest. Female Rural students were not statistically different than any of the other three groups for this test. No differences were found between Male Urban and Female Urban students on the DAT:SR test. Effect size was small or minimal ($\eta = .07$) (Cohen, 1988; Vaske, 2008).

For the PSVT:R, differences were statistically significant between Male Rural students and the three other groups, with Male Rural students scoring highest. Effect size was between small or minimal and medium or typical ($\eta = .16$).

The results from the LAP test showed statistically significant differences between Male Rural and the other 3 groups, with Male Rural students scoring higher. No differences were found between Female Rural - Male Urban and Urban Males - Females. The effect size was between small or minimal and medium or typical ($\eta = .17$).

**Table 2. Gender and Location relating to performance on spatial skills tests**

| | Male Rural | Female Rural | Male Urban | Female Urban | *F*-value | *p*-value | Eta (η) effect size |
|---|---|---|---|---|---|---|---|
| DAT[1] | $4.59^{a}$ | $4.31^{a,b}$ | $4.24^{b}$ | $4.24^{b}$ | 4.16 | .006 | .07 |
| PSVT[1] | $4.27^{a}$ | $3.56^{b}$ | $3.56^{b}$ | $3.32^{b}$ | 22.91 | < .001 | .16 |
| LAP[1] | $3.23^{a}$ | $2.71^{b}$ | $2.49^{b,c}$ | $2.33^{c}$ | 20.51 | < .001 | .17 |
| MCT[1] | $2.77^{a}$ | $2.74^{a}$ | $2.37^{b}$ | $2.24^{b}$ | 10.28 | < .001 | .13 |

[1]Means are on a 10-point scale with 1 point being awarded for each correct answer. Means with different letter superscripts in each row are significant at $p < .05$ based on Tamhane's T2 post-hoc test for unequal variances. [a,b,c] superscripts indicate where the statistically significant differences were found.

Results from the MCT test showed statistically significant differences between Rural and Urban students (both for male and females) with rural students scoring higher on the test compared to their urban counterparts. The effect size was between small or minimal and medium or typical (η = .13). Overall, Rural Males performed statistically better than Urban Males on all spatial skills tests.

No statistically significant differences were found between Male and Female Rural students on the DAT and MCT. Male Rural students performed statistically significantly higher on PSVT and LAP in comparison to the other three groups.

The hypothesis is partially accepted as males from rural locations performed significantly better on spatial skills compared to males and females in urban locations but the same was not always true for rural females.

**Conclusions**

The results lead us to two potential explanations. First, a rural location has a greater impact on male students compared to female students as the data showed that rural males outperformed urban males and females on all spatial tests. Conversely, statistical significance for rural females outperforming urban males and urban females was found on one test (MCT). This could suggest that rural females are not experiencing the rural environment in a similar manner that rural males are. For example, rural males might be assisting in farm work while rural females may not be included in these activities.

Our findings indicate that the spatial skills of rural and urban students vary between genders in some cases. Future work will examine if the trend found here persists into grades 8 and 9. Additionally, we plan to examine the impact of a spatial curriculum intervention on rural and urban students to see if the impact varies by gender or by school location.

Understanding if these differences in spatial skills narrow or widen into high school and ultimately university will assist in developing interventions earlier in a student's education and help prepare students for entering engineering programs. Improving the spatial skills of all students could contribute to a greater diversity of engineering students by not eliminating students from an early stage. Additionally, understanding the spatial skills of rural students can help provide more targeted interventions that are aimed at STEM participation.

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