

Socioeconomic Status and Spatial Visualisation: An Examination of Rural-Urban Differences

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Abstract

To create an engineering-capable workforce, the talent from people of all demographic backgrounds must be sought. One method of identifying this talent is by measuring their spatial skills. Spatial skills have been shown to be a better predictor of success in engineering degree attainment compared to other testing measures, including mathematics. Additionally, success in engineering has been linked to a students' spatial skills. But most work has focused on students from urban settings. Through exploring the spatial skills of rural students from low social economic backgrounds, we aim to leverage the skills of these students that are often underrepresented in the engineering workforce.

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1 BACKGROUND

Creating an engineering-capable workforce requires the talent of people from all demographic backgrounds to be represented [1]. Increasing participation in engineering relies upon attracting and retaining students from varying backgrounds that more accurately reflect the population. Attracting and retaining a diverse population to engineering is important not only for social justice reasons but also to solve the grand challenges of today and in the future. One promising method for



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improving retention rates of women engineering students is by helping students improve their 3D spatial visualisation skills [e.g. 2 - 4]. Spatial visualisation is a common practice in engineering and is the ability to conceptualise real and imagined spatial relationships including being able to mentally manipulate, organise, and reason about these relationships [e.g. 5]. Engineering students with well-developed 3D spatial visualisation skills have been shown to persist and do better in engineering courses compared to their lower skilled counterparts [6,7].

Spatial Cognition has been an area of research in psychology for more than 100 years and significant gender differences (favouring males) have been found throughout that time [e.g. 6-9]. Research has also shown differences in spatial ability between students from low Socio-Economic Status (SES) groups and their more affluent peers (favouring affluence) [10]. Since spatial skills are known to be critical to success in engineering, this means that women and students from low SES groups are at a disadvantage when pursuing engineering studies. Poorly developed spatial skills for these populations could be a hindrance to our ability to diversify engineering.

Most spatial skills research has focused on urban populations when studying students from different SES backgrounds. However, no studies (to our knowledge) have examined if locale modifies SES differences. Additionally, students from rural areas are 32.2% less likely to pursue post-secondary education compared to nonrural youth, which provides an opportunity to determine ways in which this often underserved demographic group can be supported and encouraged as we strive to create a diverse engineering-capable workforce [11]. Therefore, this paper aims to gain a better understanding of how locale interacts with SES status relevant to spatial skills.

2 PURPOSE

The purpose of this paper is to explore if differences in spatial skills exist in urban and rural children of differing SES levels. The following two hypothesis will be tested:

Hypothesis 1: There will be a significant difference in the spatial skills of students in rural locations compared to the spatial skills of students in urban locations.

Hypothesis 2: There will be a significant difference in the spatial skills of low SES students in rural locations compared to the spatial skills of low SES students in urban locations.

3 METHODS

3.1 Sample

The data used in the analysis presented here was collected in 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 25,000 residents. A majority of the students were of white/non-Hispanic race. The data were collected from grade 7 and grade 8 (ages 12-13) science and mathematics classrooms. Approximately 3,000 students participated and were evenly split between low and medium/high SES (1490 vs. 1489). A student was categorised as low SES if they qualified for free or reduced-price lunch (a federal program in the United States that requires near poverty level income).

3.2 Testing Instruments

A total of four tests were administered during grade 7 (PSVT:R, DAT, LAP & MCT) and two tests during grade 8 (PSVT & DAT). The tests are explained in greater detail in the following section.

The Purdue Spatial Visualization Test: Visualization of Rotation (PSVT:R) was used to measure students' 3D mental rotation skills [12]. An example of a PSVT:R question can be found in Figure 1. The Differential Aptitude Test (DAT) assesses students' abilities to take a 2D pattern and predict what would be formed in 3D after it was folded [13]. An example of the DAT task can also be found in Figure 1. Each correct response was given 1 point when scoring the tests.

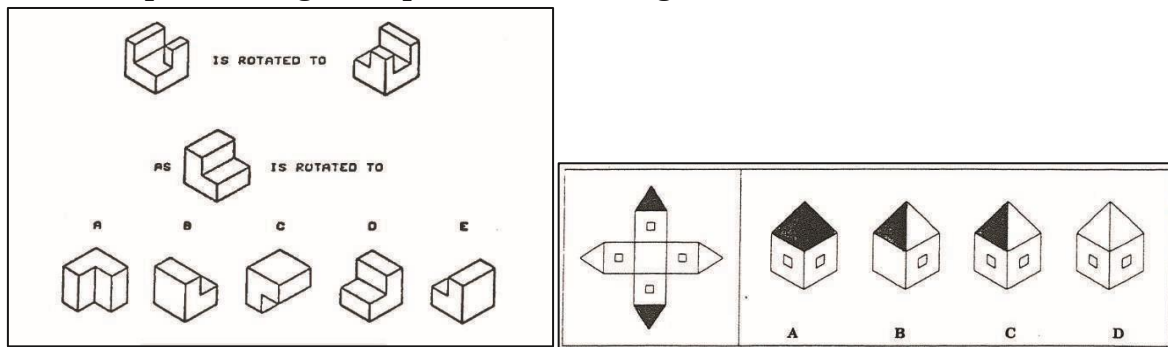
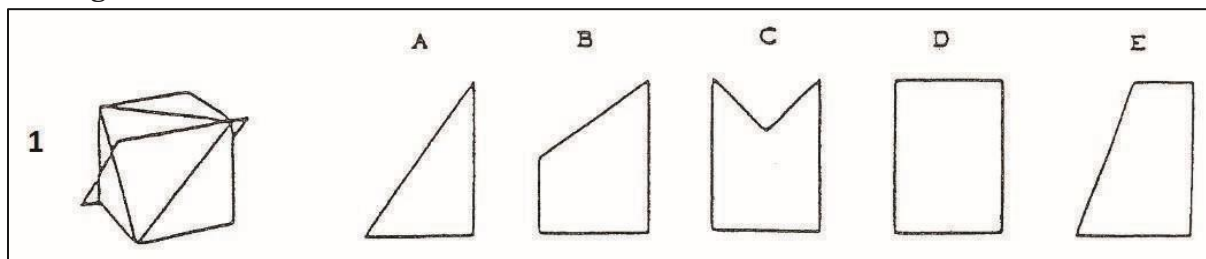


Figure 1. Example of a PSVT:R (left) and DAT (right) problem that students were asked to solve

The Mental Cutting Task (MCT) focuses on the ability of a person to imagine what a cross section of an object would look like if sliced by an imaginary plane [14]. The Modified Lappan Test (LAP) tests students' ability to dissect orthogonal views and relate them to coded plans [15]. An example of a MCT (top) and LAP (bottom) test question can be found in Figure 2. Each correct response was given 1 point when scoring the tests.



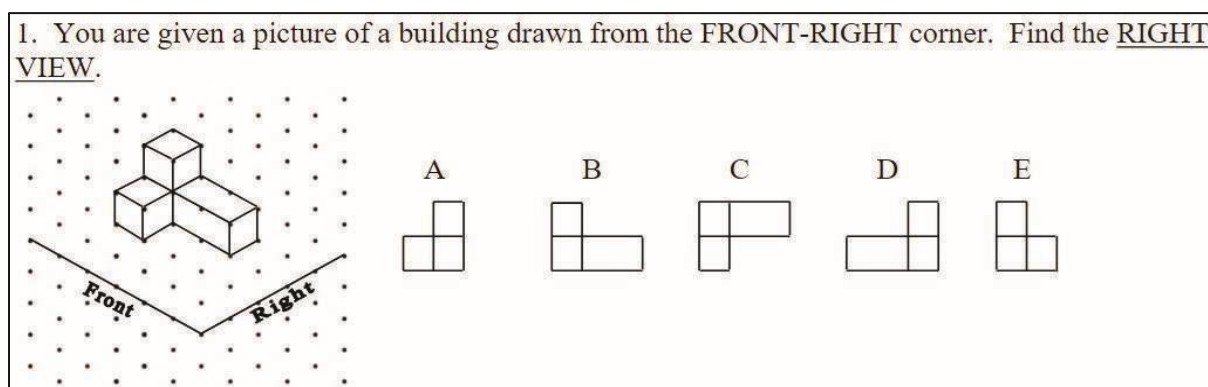


Figure 2. Example of a MCT (top) and LAP (bottom) question presented to students

3.3 Data Collection

Data collection occurred sometime in the second semester (~March) of both grade 7 and grade 8. Testing was spread out over at least two class periods and was conducted by the math or science teacher at each respective school. Testing included the PSVT:R, DAT, LAP, and MCT in grade 7. The LAP and MCT were eliminated for grade 8 testing due to time limitation concerns expressed by the teachers and therefore only DAT and PSVT:R data is presented for grade 8.

3.4 Data Analysis

Responses were analysed using IBM SPSS where both descriptive statistics and an independent sample t-test were used to test the differences between locations (urban/rural) and SES to students' performance on the spatial skills tests.

4 RESULTS

Hypothesis 1: There will be a significant difference in the spatial skills of students in rural locations compared to the spatial skills of students in urban locations.

Means for urban and rural students were dissimilar on all six spatial skills tests, ranging from 2.30 to 4.68 for urban students and 2.76 to 5.12 for rural students (Table 1). Hypothesis 1 was accepted ($2.67 < t < 6.32$, $p < .008$). Effect sizes were small or minimal ($.05 < r_{pb} < .13$)[16-17]. Overall, rural students statistically scored higher on the spatial skills tests than the urban students.

Table 1. Rural and urban Students' Spatial Skills Tests Scores¹

	Urban	Rural	Independent sample <i>t</i> -value	<i>p</i> -value	Effect size (<i>r_{pb}</i>)
7DAT	4.23	4.45	2.67	.008	.05**
7PSVT	3.44	3.93	5.63	< .001	.11**

7LAP	2.41	2.99	6.32	< .001	.13**
7MCT	2.30	2.76	5.62	< .001	.12**
8DAT	4.68	5.12	3.44	.001	.09**
8PSVT	4.05	4.69	4.76	< .001	.12**

**Correlation is significant at the 0.01 level (2-tailed)

¹ Means are on a 10-point scale with 1 point being awarded for each correct answer.

Hypothesis 2: There will be a significant difference in the spatial skills of low SES students in rural locations compared to the spatial skills of low SES students in urban locations.

Means for Low SES students in urban and rural locations were dissimilar on all six spatial skills tests, ranging from 2.13 to 4.18 for urban students and 2.72 to 4.87 for rural students (Table 2). Hypothesis 2 was accepted ($3.48 < t < 6.81, p < .001$). Effect sizes were between small or minimal and medium or typical ($.10 < r_{pb} < .19$) [16-17]. Overall, Low SES students in rural locations statistically scored higher on the spatial skills tests than low SES students in urban locations.

Table 2. Low SES Students in rural and urban Locations Spatial Skills Test Scores¹

	<u>Low SES</u>		Independent sample <i>t</i> value	<i>p</i> -value	Effect size (<i>r_{pb}</i>)
	Urban	Rural			
7DAT	3.83	4.23	3.48	.001	.10**
7PSVT	2.89	3.70	6.81	< .001	.19**
7LAP	2.14	2.80	5.73	< .001	.17**
7MCT	2.13	2.72	5.48	< .001	.17**
8DAT	4.18	4.87	3.96	< .001	.15**
8PSVT	3.68	4.44	4.19	< .001	.16**

**Correlation is significant at the 0.01 level (2-tailed)

5 DISCUSSION

Spatial visualisation skills have consistently and statistically been found to be an independent predictor of engineering career selection and attainment of an advanced engineering degree [18]. Multiple studies have also shown a link between spatial skills and introductory engineering courses [7, 19, 20]. Additionally, research has found that spatial skills are linked to creativity and technical innovation [21]. Thus, it is evident the importance of well-developed spatial skills for success in engineering.

Ensuring success of students in grade 7 mathematics is one way to assist in increasing the number of students from a range of demographic backgrounds who pursue engineering. Further developing students' spatial skills through training and support may lead students to take higher-level mathematics courses in high school, which would put the students in a better position to ultimately pursue engineering in post-secondary education.

Most current efforts aimed at diversifying engineering provide students with engaging interventions to combat the stubborn problem of a lack of diversity. *Science is fun! Women can be engineers! Engineers and scientists solve interesting societal problems!* All of these efforts are engaging and rewarding for the young women who participate in them, but they are missing a key component. Working on *affective* issues without solving underlying *cognitive* issues will likely not solve the problem of a lack of diversity in engineering. Spatial skills show some of the most robust and persistent gender and SES differences in cognition. Since spatial skills are important to success in engineering, students with poor spatial skills will be at a disadvantage if they do eventually overcome the stereotypes and pursue an engineering career. Efforts to improve engineering diversity that are aimed at only the affective while ignoring the cognitive do so at their peril. A holistic approach is needed if we are to be successful in our efforts to increase diversity in engineering.

Understanding which students would benefit the most from spatial skills training (e.g., urban low SES, women, etc.) will allow us to target resources and effort where it is needed most. Further, since it appears that spatial skills of rural low SES students do not appear to be significantly lower than those of their more affluent peers, perhaps spatial skills training for this group is not as critical and resources could be focused on affective issues in these locales.

6 CONCLUSION

In summary, the results show that students from rural settings score higher on spatial tests compared to their urban counterparts. More specifically, when looking at SES status, we see that low SES students in rural locations outperform low SES students in urban settings.

Our findings indicate the need to create recruitment strategies specific to rural students to help boost their participation rates in university. Additionally, the findings here support further inquiry into determining the aspects of rural life that contribute to developing better spatial skills compared to urban settings. While some research has already found differences in the type of language used to describe spatial relations (rural use geocentric and urban use egocentric), future research can consider additional factors such as parental involvement and activity type [22].

REFERENCES

- [1] National Science Board, (2018). Science and Engineering Indicators 2018. Alexandria, VA: National Science Foundation (NSB-2018-1).
- [2] Veurink, N. L., & Sorby, S. A. (2019). Longitudinal study of the impact of requiring training for students with initially weak spatial skills. *European Journal of Engineering Education*, 44(1-2), 153-163.

- [3] Sorby, S. A. (2009). Educational research in developing 3-D spatial skills for engineering students. *International Journal of Science Education*, 31(3), 459-480.
- [4] Sorby, S., Veurink, N., & Streiner, S. (2018). Does spatial skills instruction improve STEM outcomes? The answer is 'yes'. *Learning and Individual Differences*, 67, 209-222.
- [5] Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: A meta-analysis of training studies. *Psychological Bulletin*, 139(2), 352-402
- [6] Sorby, S. A., Casey, B., Veurink, N. & Dulaney, A., (2013), The role of spatial training in improving spatial and calculus performance in engineering students. *Learning and Individual Differences*, 26, 20-29.
- [7] Veurink, N. L., & Sorby, S. A. (2011, June), Raising the Bar? Longitudinal Study to Determine which Students Would Benefit Most from Spatial Training Paper presented at 2011 ASEE Annual Conference & Exposition, Vancouver, BC.
- [8] Linn, M. C. & Petersen, A.C., (1985). Emergence and Characterization of Sex Differences in Spatial Ability: A meta Analysis, *Child Development*, Chicago, Ill., Vol.56.
- [9] Wei, W., Chen, C., & Zhou, X. (2016). Spatial ability explains the male advantage in approximate arithmetic. *Frontiers in psychology*, 7, 306.
- [10] Levine, S. C., Vasilyeva, M., Lourenco, S. F., Newcombe, N. S., & Huttenlocher, J. (2005). Socioeconomic Status Modifies the Sex Difference in Spatial Skill. *Psychological Science*, American Psychological Society, 16(11) 841- 845.
- [11] Byun, S., Meece, J., & Irvin, M. (2010, April). Rural-nonrural differences in educational attainment: Results from the National Educational Longitudinal Study of 1988-2000. Paper presented at the annual meeting of the American Educational Research Association, Denver, CO.
- [12] Guay, R. B., (1977). Purdue Spatial Visualization Test: Rotations, West Lafayette, IN, Purdue Research Foundation.
- [13] Bennett, G. K., Seashore, H. G., & Wesman, A. G. (1973). Differential Aptitude Tests, Forms S and T. New York: Russell Sage Foundation.
- [14] CEEB (1939). Special Aptitude Test in Spatial Relations. College Entrance Examination Board, USA.
- [15] Lappan, G. (1981). Middle Grades Mathematics Project, Spatial Visualization Test, Michigan State University.
- [16] Cohen, J., (1988). Statistical power analysis for the Behavioural sciences, 2nd ed., Lawrence Erlbaum Associates, Hillsdale, NJ.

- [17] Vaske, J., (2008), *Survey research and analysis: Application in parks, recreation and human dimensions*, Venture, State College, PA.
- [18] Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology*, 101(4), 817–835.
- [19] Sorby, S. A. (2000). Spatial abilities and their relationship to effective learning of 3D modeling software. *Engineering Design Graphics Journal*, 64(3), 30–35.
- [20] Branoff, T. J. (2014). Examining the constraint-based modeling strategies of undergraduate students. In *Proceedings of the 69th Engineering Design Graphics Division Midyear Conference*, Normal, IL, 54– 66. Retrieved from <http://edgd.asee.org/conferences/proceedings/69th%20Midyear/69th%20Proceedings.pdf>.
- [21] Kell, H. J., Lubinski, D., Benbow, C. P., & Steiger, J. H. (2013). Creativity and technical innovation: Spatial ability's unique role. *Psychological Science*, 24(9), 1831–1836.
- [22] Dasen, P. R., & Mishra, R. C. (2010). *Development of geocentric spatial language and cognition: An eco-cultural perspective* (Vol. 12). Cambridge University Press.