Spatial Ability Improvement and Curriculum Content

Patrick E. Connolly
Department of Computer Graphics Technology, Purdue University

Abstract

There has been a significant history of research on spatial ability and visualization improvement and related curriculum content presented by members of the Engineering Design Graphics Division over the past decade. Recently, interest in this topic has again been heightened thanks to the work of several division members on research such as the EnViSIONS project, among others. This paper reviews the foundational history of spatial visualization curriculum research in the division and explains recent research carried out in this area by the author. Research outcomes are reported, along with an analysis and proposed explanation of results for the first round of testing in this specific class. Recommendations for future studies are proposed in this area of research.

I. Foundation History

As graphics educators, we of the Engineering Design Graphics Division of the American Society of Engineering Education have always expressed an interest in the impact and improvement of our instructional content. Likewise, the study, development, and enhancement of spatial visualization ability in our students has been a continuous point of focus for research and study. Even a superficial review of publications and presentations within the EDGD show a long history of scholarship in the area of curriculum development relating to spatial skills. Miller (1996) noted the deep and solid foundation of early pioneering research in spatial development from the 1920's through 1940 in a predecessor organization to the Engineering Design Graphics Division. Significant work in this early period involved the development and application of spatial ability testing in college curricula. Instructional recommendations from this time frame included a focus on descriptive geometry and multiview drawing to enhance visualization ability. The emphasis on descriptive geometry and orthographic drawing strengthened during and after the World War II years, and grew to include an emphasis on freehand sketching. Beginning with the 1960's, instructional recommendations expanded to include 2D to 3D transformations, isometric images, and real models. As the computer evolved into a graphics workbench in the 1970's and beyond, the use of virtual images, interactions, and rendering were added to the teaching 'toolbox' for visualization enhancement.

Beginning in the 1990's, there seems to have been a resurgence in focus within the division on curriculum planning for engineering graphics. Miller and Bertoline (1991) reviewed the history of spatial ability research and development theory, and reemphasized the need for, and connection between, such research and curricular direction. Sexton (1992) noted the importance of appropriate content and method, as well as duration of exposure, of curricula in order to effectively impact students' spatial development. He recommended a 3D CAD emphasis that leveraged the power of the virtual model to speed visualization improvement. This direction was reinforced by Bertoline (1993), who described the changes impacting industrial applications due to 3D computer capabilities. His recommendations for curriculum adjustment included many "broadening" skill sets such as simulation, analysis, rendering, and other areas where the power of the virtual database could be applied across the product lifecycle. These modern applications were to be mixed with traditional visualization developing instruction, resulting in curricular areas such as geometry, modeling theory, Boolean interaction, and 3D to 2D transitioning, among others.

Barr (1999) discussed the future curriculum for the 21st century. He noted that, in a survey of graphics educators, the most important rated topic for inclusion in an engineering design graphics curriculum was the development of 3D visualization skills. Other highly rated subject areas included 3D modeling, sketching, and orthographic projection. Similar topics were also emphasized by Ault (1999), Miller (1999), and Smith (2003). A focus on visualization skill development was a primary focus of a model curriculum for introductory graphics courses in a paper by Branoff, Hartman, and Wiebe (2002). Recommended content areas for the course included sketching, 3D modeling, Orthographic projection, pictorial imaging, and geometry.

One of the most prolific researchers and authors in the Engineering Design Graphics Division in the area of spatial skill development, remediation, and curriculum development has been Dr. Sheryl Sorby (Sorby & Baartmans, 1996; Sorby & Gorska, 1998; Sorby, 1999; Sorby, 2001; Sorby, 2005). She has shown that instructional content in isometric sketching, orthographic projection, pattern development, rotations, object cross-sectioning, and Boolean interactions of solids. Dr. Sorby has also validated that a curricular focus in spatial skill development helps to retain students in engineering and technology related fields.

Researchers outside of the EDGD have also contributed to this topic. Fields (1999) recommended a heavy emphasis on sketching from artifacts and mental images as a means of developing spatial visualization in engineering students. He noted that the deletion of descriptive geometry from the typical engineering curriculum had resulted in the decline of student ability in spatial tasks. Contero, Company, Saorin, and Naya (2006) also described the continued importance of spatial reasoning in the engineering curriculum, and that it should be taught using sketching as well as modern technology. From their perspective, emphasis should be placed on orthographic projection skills, mental imagery of 3D objects, and the use of web-based drills, interactive multimedia, and tutorials.

II. The CGT 116 Course

The author has taught an introductory engineering design graphics course to computer graphics technology and industrial design students at Purdue University for a number of years. This course, CGT 116, Geometric Modeling for Visualization and Communication, requires the students to plan, visualize, create, and manipulate 3D solid and surface models in several high-end parametric and NURBS-based computer graphics software packages. However, since one of the desired outcomes for the course is the development and strengthening of spatial visualization skills, the students are also engaged in a number of theory lectures and practical assignments involving many of the same topics as described earlier from the lengthy history of the Engineering Design Graphics Division. These include sketching assignments, 2D and 3D geometry applications, orthographic and pictorial imaging, and Boolean interactions.

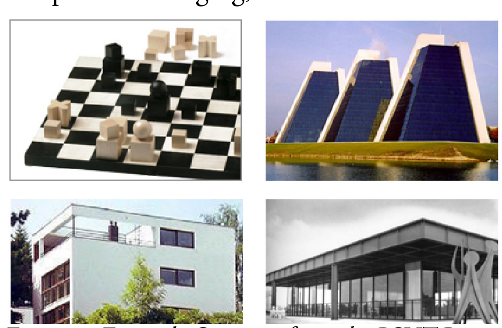

Figure 1. Example Question from the PSVT:R.

III. Spatial Testing

In order to validate the impact of the course instructional content on students' spatial development, testing was done in a recent 16 week semester-long CGT 116 class. Students were given the Purdue Spatial Visualization Test: Rotations (PSVT:R) (see Figure 1) as a pretest during the first week of instruction and as a posttest during the final week the class met.

Mean scores and paired t-test results were examined to see if improvement in spatial skill could be identified as measured by this test instrument. A total of 77 students took either the pre- or posttest. The mean score for the pretest was 23.88 (out of 30 possible); the posttest mean score was 25.30. The difference in scores (mean posttest – mean pretest) showed a difference of 1.47. Paired t-test results for the 54 students that completed both the pre- and posttests showed an improvement in scores that was statistically significant (t =3.56, df =53, p<.001) (see Table 1).

Table 1. Test Results for All Paired Students.

All Paired Students (n=54)		
Pretest Mean	*Posttest Mean*	*Mean Difference*
23.83	25.30	1.47
t	**df**	**p**
3.56	53	<.001

33 students that completed both the pretest and posttest scored less than 26 on the pretest. The mean data for this group showed a pretest score of 21.24, and for the posttest a mean score of 23.88. The difference in mean scores (posttest – pretest) showed a mean improvement of 2.64. Paired t-test results for this group also showed that the improvement was statistically significant (t = 4.82, df =32, p< .0001) (see Table 2).

Table 2. Test Results for Pretest < 26.

Pretest Score < 26 (n=33)		
Pretest Mean	*Posttest Mean*	*Mean Difference*
21.24	23.88	2.64
t	**df**	**p**
4.82	32	<.001

Eleven students that completed both test iterations scored lower than 21 on the pretest. The mean scores for this group were pretest = 17.55, posttest = 20.64. The group's mean difference was equal to 3.09. The paired t-test results for this smaller group was also statistically significant (t=2.64, df = 10, p < .02) (see Table 3).

Table 3. Test Results for Pretest < 21.

Pretest Score < 21 (n=11)		
Pretest Mean	*Posttest Mean*	*Mean Difference*
17.55	20.64	3.09
t	**df**	**p**
2.64	10	<.02

Although the pretest result < 21 group is small (n=11), if these results are examined in conjunction with the pretest < 26 (n=33) group and the overall paired group (n=54), it would appear that the curriculum content for the CGT 116 class had a positive impact on the spatial ability of the students as measured by the PSVT:R instrument. Furthermore, for students that did not exhibit high spatial ability as measured by the pretest, experiencing the class content seemed to provide more improvement in spatial skill development than for those who scored higher on the pretest. This would seem to support the premise that properly applied curriculum content as described in this paper can be an effective remediation tool for students with lower spatial skill levels. These results are promising, but must be regarded in the context of variables that could not be controlled in the study. Such items as the influence of other academic courses being taken simultaneously or extracurricular activities could not be accounted for in these data.

IV. Further Research

The long history of curriculum content focused on spatial visualization and development is a strength of the Engineering Design Graphics

Division. Our members have been involved in research and application in this area for many decades. As technology continues to progress, classroom and laboratory techniques also must adapt. However, certain proven aspects of instructional content must be maintained, especially that which has been shown to enhance student spatial ability.

Our division must continue to research in this realm. Studies such as the multi-university EnViSIONS project add greatly to our knowledge base. We must continue to research spatial test instruments, examine manual, computer, and web-based methods to enhance spatial skills, and explore cognitive connections between teaching and learning in our discipline.

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