AC 2008-1112: IMPACT OF SPATIAL VISUALIZATION TOPIC ORDER ON STUDENT PERFORMANCE AND ATTITUDES

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Impact of Spatial Visualization Topic Order on Student Performance and Attitudes

Abstract

Spatial visualization skills are critical to many scientific and technical careers. At Michigan Tech, we identify first year engineering students who may not have fully developed their spatial skills and invite them to take an optional 1-credit course to help develop these skills. This class meets for 1.5 hours once a week for 14 weeks. The topics covered in this class include: isometric drawing, orthographic projections, flat patterns, 3-D rotations, object reflections and planes of symmetry, cutting planes, surfaces and solids of revolution, and combining solids. Topics are listed in the order that was thought to develop 3-D spatial skills and in the order they have been traditionally covered in this class.

In the past we have noticed that 1) some students have a difficult time jumping right into isometric sketching and 2) that by the end of the semester students seem bored, especially when coving the topics of surfaces and solids of revolution and combining solids. To determine if attitudes and learning at the beginning and end of the course could be improved, the order of topics covered was altered in one of the three sections of the spatial visualization course during the Fall 2007 semester. At the same time, we wanted to ensure that changing the order in which topics were covered did not negatively impact improvements in spatial skills that we have been able to achieve through this course. Therefore, students in all sections were pre- and post-tested to determine whether changing the order of topics had a negative impact on spatial skill development. Attitudes of students taking the course with the traditional order of topics were compared to attitudes of students taking the course with the modified order through weekly evaluation forms. The evaluation form asked students to rate things such as their perception of the difficulty of the topic, how much time they spent on the material outside of class, and their enjoyment of the material covered.

It was found that the new order of course material did not have an impact on the development of spatial skills or student perception of the difficulty of the material. However, students did show a slight improvement in their overall enjoyment of the material. This improvement was statistically significant for the module on combining solids which was moved to the beginning of the semester. The improvement in enjoyment was also significant for some of the more difficult modules, inclined and curved surfaces and rotations about a single axis.

Introduction

The spatial skills of all first year engineering students at Michigan Technological University are evaluated by administering the Purdue Spatial Visualization Test: Rotations[1] during Freshman Orientation. Students who have difficulty with this test, those scoring 18 or less out of a possible 30 points (60% or lower), are encouraged to enroll in an optional 1-credit course to help them further develop their spatial skills.

This course meets one day a week throughout the fourteen week semester. Of the fourteen sessions, one is used for pre-testing and another three are used for quizzes. During the remaining ten class periods the students work through the modules in an "Introduction to Spatial Visualization: An Active Approach" software and workbook[2]. In addition to the nine workbook and software modules, isometric and orthographic drawings of inclined and curved surfaces is introduced using only sketching exercises (there is no software component for this topic). Each class begins with a short, 10-15 minute lecture that includes example problems. Students then work through the software portion of the module, and move onto workbook problems after completing the software module. The order in which the topics have traditionally been covered follows the order of the workbook with the exception of the Inclined and Curved Surfaces module. This order is listed in Table 1 in the "Comparison Group" column.

The topics in the workbook are arranged in an order which were believed to develop spatial skills. In an interview with Beverly Baartmans[3], one of the original developers whose work formed the basis for the workbook, it was explained that since 2-D spatial skills are developed before 3-D spatial skills, the topics in the workbook were ordered such that the topics of isometric sketching, orthographic projection, and flat patterns which bridge 2-D to 3-D were covered first. Topics such as surfaces and solids of revolution and combining solids, which are considered to be more strictly 3-D in nature, were covered at the end of the workbook.

In the past several years we have noticed that 1) some students have a difficult time jumping right into isometric sketching which uses both 2-D and 3-D skills and 2) that by the end of the semester students seem bored especially when covering some of the 3-D skills, particularly surfaces and solids of revolution and combining solids. In this study we investigated if changing the order in which the modules are covered has an impact on the development of spatial skills or on student attitudes.

Methods

Three sections of ENG1002: An Introduction to Spatial Visualization were offered in the Fall of 2007 at Michigan Tech University. In one of the sections, the order of instruction was varied compared to the other two sections. Section 1, the experimental group, contained 17 students (9 male, 8 female). As shown in Table 1, for the experimental group, the last two modules covering 3-D skills (Module 8 – Surfaces and Solids of Revolution and Module 9 – Combining Solids) were moved to the beginning of the course, followed by Module 3 – Flat Patterns. The remaining modules were covered in the order they appeared in the workbook. In the comparison group, Sections 2 and 3, the modules were completed in the order in which they appear in the workbook, which is the order in which they have been traditionally covered in the course since 2000. Sections 2 and 3 consisted of 13 (6 male, 7 female) and 20 (10 male, 10 female) students, respectively.

Table 1: Order in which modules were covered.

Week	Experimental Group (Section 1)	Comparison Group (Sections 2 & 3)
1	Pre-testing	Pre-testing
2	Module 8 – Surfaces and Solids of Revolution	Module 1 – Isometric Drawings and Coded Plans
3	Module 9 – Combining Solids	Module 2 – Orthographic Drawings
4	Module 3 – Flat Patterns	Inclined and Curved Surfaces
5	Module 1 – Isometric Drawings and Coded Plans	Module 3 – Flat Patterns
6	Quiz	Quiz
7	Module 2 – Orthographic Drawings	Module 4 – Rotations about a Single Axis
8	Inclined and Curved Surfaces	Module 5 – Rotations about 2 or more axes
9	Module 4 – Rotations about a Single Axis	Module 6 – Object Reflections and Symmetry
10	Quiz	Module 7 – Cutting Planes and Cross Sections
11	Module 5 – Rotations about 2 or more axes	Quiz
12	Module 6 – Object Reflections and Symmetry	Module 8 – Surfaces and Solids of Revolution
13	Module 7 – Cutting Planes and Cross Sections	Module 9 – Combining Solids
14	Quiz	Quiz
Final Exam	Post-testing	Post-testing

Development of spatial skills: Pre- and post-tests

To determine if the order in which the modules are presented affects the development of spatial skills, pre- and post-test scores for the different sections are compared. The students completed the following tests at the beginning and end of the course: Purdue Spatial Visualization Test: Rotations[1], 10 questions from the modified Lappan Test, and 10 questions from the Mental Cutting Test (a sub-set of CEEB Special Aptitude Test in Spatial Relations[4]).

The class average pre-test scores, post-test scores, and gains were compared for the two sections that comprised the comparison group. It was found that there was no significant difference in mean scores or in mean gains so the two sections were combined into a single comparison group for this study. The average pre- and post-test results for the experimental and comparison groups are shown in Table 2. As shown, the pre-test scores are nearly identical between the two groups, with no statistical difference between the means. Since there is not a difference in initial spatial skills between the experimental and control groups, any difference in the post-test scores and their resulting gains should be due to the different order of instruction. However, the small differences between the average post-test scores and gains for the experimental and control groups are not statistically different. Therefore changing the order in which the modules were covered did not impact the development of students' spatial skills s measured by these testing instruments.

Table 2: Average Pre- and Post-test scores for students in the experimental and comparison groups.

	Experimental Group			Comparison Group			Significance	
	Pre-test	Post-Test	Gain	Pre-test	Post-Test	Gain	Pre-test	Gain
PSVT:R	15.4 (n=17)	23.6 (n=17)	8.29 (n=17)	15.4 (n=31)	23.2 (n=33)	8.4 (n=31)	>0.4	>0.4
Lappan	5.9 (n=17)	8.1 (n=17)	2.2 (n=17)	6 (n=33)	7.4 (n=33)	1.6 (n=32)	>0.4	0.2
MCT	4.8 (n=17)	7.7 (n=17)	2.9 (n=17)	4.8 (n=33)	7.4 (n=33)	2.8 (n=32)	>0.4	0.4

Student Attitudes

Students in Sections 1 (experimental group) and 3 (subset of comparison group) were asked to complete a module evaluation form at the completion of each module. To determine if student attitudes are affected by the order in which the modules are presented, pertinent portions of the evaluation form were examined. These questions, shown in Figure 1, were designed to quantify student difficulty with the material (Questions 1-3) and overall student enjoyment of the material (Question 4). We expected that changing the order of the modules would 1) decrease difficulty with the material, particularly for the topics of isometric sketching and orthographic projection, and students would therefore spend less time completing homework outside of class and 2) improve overall student enjoyment. Average student responses to these questions for each of the modules are summarized in Tables 3-6.

EVALUATION OF MODULE BY STUDENTS

Please take a few minutes to fill out this evaluation form. Your responses will help us arrange future materials to fit the needs of students.

Title of Module: ____

1. The length of the module with respect to the activities was:

1	2	3
too short	appropriate	too long

2. For my learning purposes, the overall level of this module was:

1	2	3
too simple for my needs	appropriate to my needs	too advanced for my needs

3. Approximately how much time did you spend on this module outside of class?

4. Overall, I enjoyed this module.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Feel free to use the back of this form for any additional comments.
THANK YOU! *Please return your completed form to the envelope provided.*

Figure 1: Module evaluation questions.

Tables 3 and 4 include the data from the questionnaires for Question 1 (length of module) and Question 2 (level of difficulty of module), respectively. The data presented in these tables show that the students in both the experimental and comparison groups thought that the modules took the appropriate amount of time and were at the appropriate level of difficulty for their learning needs. Slight differences between mean ratings for each group were not statistically significant.

Table 3: Question 1 - Length of module.

Module #	Section 1 (Experimental)	Section 3 (Comparison)	Significance (p)
1	2	1.95	0.3
2	2.18	2.12	0.4
Incl. & Curved Surfaces	2.19	1.92	0.2
3	2	2	0.3
4	2.11	2	0.3
5	2.13	2	0.1
6	2.09	2	0.2
7	2	2.06	0.3
8	2	2.06	0.3
9	2	1.83	0.2

Table 4: Question 2 – Level of module.

Module #	Section 1 (Experimental)	Section 3 (Comparison)	Significance (p)
1	2	1.8	0.2
2	1.91	1.77	0.2
Incl. & Curved Surfaces	1.86	1.83	>0.4
3	2	1.94	0.3
4	2.11	2	0.1
5	2.13	2	0.1
6	2	2	
7	2	2	>0.4
8	1.94	1.77	0.2
9	1.94	1.78	0.2

The average amount of time students spent outside of class completing the homework assignments is shown in Table 5. It was expected that if students found a particular module "easier," they would spend less time out of class completing homework for that module.

Table 5: Question 3 – Average time spent outside of class in minutes.

Module #	Section 1 (Experimental)	Section 3 (Comparison)	Significance (p)
1	23	28.6	0.4
2	40.45	36.76	>0.4
Incl. & Curved Surfaces	54.4	63.8	0.4
3	6.42	38.88	0.05
4	28.89	54.06	0.2
5	28.75	54.71	0.2
6	5.9	30	0.025
7	0	32.65	0.010
8	20.3	3.53	0.025
9	4.41	4.44	>0.4

For most of the modules, the students in Section 1, the experimental group, spent less time outside of class on average than did the students in Section 3, the comparison group except for Modules 2 and 8. However, the differences in the means were not significant for Modules 1, 2, and Inclined and Curved Surfaces, which is where we expected to see the greatest reduction in time. There was a significant difference in the time students spent outside of class for Modules 3, 6, 7, and 8. Since Module 8 was the first module that the experimental group covered, the fact that they reported spending more time outside of class could merely be a reflection of the students adjusting to the expectations of a new course. The results from this analysis seem to indicate that the students in the experimental group spent less time working on difficult topics through the modification of the topic order; however, there were some irregularities noted in the data. For example, students completed instructor evaluations during week 10 which took approximately 20 minutes out of normal class time. As a result, the comparison group spent more time outside of class completing Module 7, since there was less time during the class session for completing assigned workbook sheets. Additionally, there were a couple of students in the comparison group who routinely spent considerably more time on their assignments than their peers, which may have affected the means for that group, due to the relatively small sample sizes. The results from this analysis appears to be promising, in that switching the order appears to result in a reduction in time required for homework completion, but further study is required due to these irregularities in the data.

Table 6 presents data that compares how much the students enjoyed each module. A rating of 3 indicates students were neutral in their enjoyment of the module while a rating of 4 indicates they agreed with the statement that they enjoyed the module. One of the purposes in rearranging the order of the modules in the experimental group was to see if students would have an easier time with Modules 1, 2, and the Inclined and Curved Surfaces module and to see if they appeared less "bored" with Modules 8 and 9. As can be seen from the data in Table 6, the experimental group appears to have enjoyed Module 9 more than the comparison group, and this difference was statistically significant. The other modules with a statistically significant difference in enjoyment levels were the Inclined and Curved Surface module and Module 4, the Rotations about a Single Axis module. These are usually considered to be among the most difficult modules in the course. Overall, there does seem to be a slight improvement in the students' enjoyment, and likely their motivation, by changing the order of topics in the course.

Table 6: Question 4 - Level of enjoyment.

Module #	Section 1 (Experimental)	Section 3 (Comparison)	Significance
1	3.7	3.79	0.4
2	3.18	3.53	0.3
Incl. & Curved Surfaces	3.5	2.9	0.05
3	3.5	3.29	0.3
4	3.67	3.06	0.05
5	3.38	3.29	0.4
6	3.64	3.36	0.3
7	3.4	3.29	0.4
8	Not asked	3.29	
9	3.94	3.5	0.05

Conclusions

The impact of changing the order in which topics are covered in a course designed to improve spatial visualization skills was investigated during the Fall 2007 semester. In one of the three sections of the class, topics traditionally covered at the end of the semester were moved to the beginning of the semester to determine if 1) there would be a difference in development of spatial skills as measured by standardized testing instruments, 2) students would have an easier time in completing modules on isometric and orthographic drawings, and 3) students would be less "bored" with modules on Surfaces and Solids of Revolution and Combining Solids (typically the last two modules covered in the class). Comparisons of pre- and post-test results indicate that there is not a significant difference in the development of spatial skills when the order of instruction is changed. This suggests that the students in this course can effectively begin with 3-D instruction, and then transition to topics which bridge 2-D to 3-D. Student responses to evaluation questions indicate that there is no difference in perceived difficulty of the material; however, switching the topic order may reduce the time spent on homework for some of the more difficult topics. There also appears to be a slight improvement in the students' overall enjoyment level in working with the modules.

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