What do Students and Instructors Really Think of the EnViSIONS Spatial Visualization Materials?

N.L. Veurink and A.J. Hamlin
Department of Engineering Fundamentals
Michigan Technological University, Houghton, MI 49931

ABSTRACT *- The EnViSIONS (Enhancing Visualization Skills – Improving Options aNd Success) Project tested the spatial visualization materials developed at Michigan Technological University and Penn State University, the Behrend College, at six universities and a high school Project Lead the Way course. As part of the project, students and instructors from five of the universities completed evaluation forms for each module they covered in the Introduction to 3D Spatial Visualization: An Active Approach workbook by Sorby and Wysocki. The evaluations asked participants to rate the quality and appropriateness of the material covered as well as to indentify which components (i.e. Penn State Behrend VIZ website, workbook software, workbook, manipulatives) of the module were beneficial to their learning (or instruction) of the material and which strategies they used to master the material. This paper will summarize results from both the student and instructor evaluations in order to benefit instructors using the materials and to guide improvements to the modules.*

I. Introduction

The purpose of the EnViSIONS project is to demonstrate that successful programs developed at Michigan Technological University and Penn State University, the Behrend College, to improve spatial visualization skills can be successfully integrated and transferred to other universities. By removing a barrier to success for some women we hope to improve the retention and success rate of these students who go into STEM disciplines. Through the EnViSIONS project, seven universities created a partnership to test the Penn State and Michigan Tech materials in a variety of trainings. The success of the project was measured by assessing the gain in spatial visualization skills of students taking the curriculum and through the use of evaluation instruments completed by both students and instructors.

The assessment of gains in spatial visualization skills after completing the trainings are reported in Veurink et al. (2009), Blasko, Holliday-Darr, and Trich Kremer (2009), Duff and Kellis (2009), and Connolly, Harris and Sadowski (2009). This paper summarizes the evaluation instruments completed by the instructors and students taking the trainings.

II. Background

The spatial visualization materials developed at Michigan Tech and Penn State Behrend were given to each EnViSIONS partner. Penn State Behrend developed the VIZ website (http://viz.bd.psu.edu/viz/) which has spatial visualization tasks such as the Mental Rotations Test and links to training resources. Michigan Tech developed a spatial visualization course and provided each EnViSIONS partner with its lecture materials as well as the workbook used in the course. The Michigan Tech course uses the *Introduction to 3D Spatial Visualization: An Active Approach* workbook and software by Sorby and Wysocki (2003).

These materials were adopted by each partner university in a variety of methods. These methods ranged from offering a 1-credit stand alone spatial visualization course, modifying an existing graphics course to include spatial visualization, to offering a supplemental course to targeted students. The curriculum was also used in summer bridge-type programs, a high school Project Lead the Way course, and in a teacher education course.

Some of the EnViSIONS trainings used all of the materials provided: the VIZ website and the Michigan Tech course materials (power point lectures and course workbook and software). Some of the partners felt the software covered the material well enough and did not use the Michigan Tech lecture material. Some did not have classroom computer access so they did not use the VIZ website and only demonstrated the workbook software for a few of the modules. All of the trainings used the workbook exercises in the Sorby and Wysocki workbook. More complete descriptions of the these trainings and the materials used can be found in Veurink et al. (2009), Blasko, Holliday-Darr, and Trich Kremer (2009), Duff and Kellis (2009), and Connolly, Harris and Sadowski (2009).

The Sorby and Wysocki workbook includes the following modules:

1. Isometric Sketching
2. Orthographic Projection: Normal Surfaces
3. Flat Patterns
4. Rotation of Objects about a Single Axis
5. Rotation of Objects about Two or More Axes
6. Object Reflections and Symmetry
7. Cutting Planes and Cross Sections
8. Surfaces and Solids of Revolution
9. Combining Solids.

In addition to these workbook modules, two of the universities used an additional module developed by Michigan Tech on the Orthographic Projection of Inclined and Curved Surfaces. Some of the universities used all of the workbook modules, while others used just four or five of the workbook modules.

III. Evaluation Instruments

Students and instructors were asked to complete an evaluation instrument after completing each module. The student evaluation instrument is shown in Figure 1.

The instructor evaluation instrument was nearly identical to the student evaluation, for example, Question 3 on the instructor evaluation was "For my *teaching* purposes, the overall level of this module was . . ." Instructors were not asked to report strategies for completing the module but were instead asked if they modified the course materials for the module.

Four of the universities completed the instructor module evaluation forms, while five of the universities completed the student evaluation forms representing seven different implementations of the EnViSIONS materials.

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. Overall, how would you rate the quality of this module?

1	2	3	4	5
Poor	Fair	Good	Very Good	Excellent

2. The length of the module with respect to the activities was:
____too short ____appropriate ____too long

3. For my learning purposes, the overall level of this module was:
____too simple for my needs ____appropriate to my needs ____too advanced for my needs

4. Each of the following was beneficial to my understanding of the material*
   a. Instruction (lecture and demonstration)
   b. 3-D Spatial software
   c. Workbook Problem Sets
   d. VIZ website
   e. Manipulatives (e.g., blocks)
   f. Interaction with the instructor(s)/TA(s)
   g. Interaction with other students

5. Suggest improvements for this module:

6. During this module I worked:
alone in a group of 2 in a group of 3 in a group of 4 or more

7. Briefly describe the methods or strategies that were most helpful to you as you completed this module.

*Students were asked to rate the items in question 4 as: Not Applicable, Strongly Disagree, Disagree, Agree, Strongly Agree

Figure 1: Student Module Evaluation Form

IV. Student Evaluations

The average student responses for each module of the curriculum are shown in Figures 2-7. The number of average student responses reported for each module varies, as some of the trainings covered only four or five of the nine workbook modules. The average responses across all institutions for the first three questions are shown in Table 1 for each module.

The overall quality of the modules, Question 1, was consistently rated by the students as good to excellent at all institutions, except for the module on Rotations about a Single Axis. As shown in Figure 2, this module also had the largest range of responses. As shown in Table 1, when the responses were averaged across all institutions, modules 6) Reflections and Planes of Symmetry and 1) Isometric Drawings had the highest quality ratings of 3.9 and 3.8, respectively.

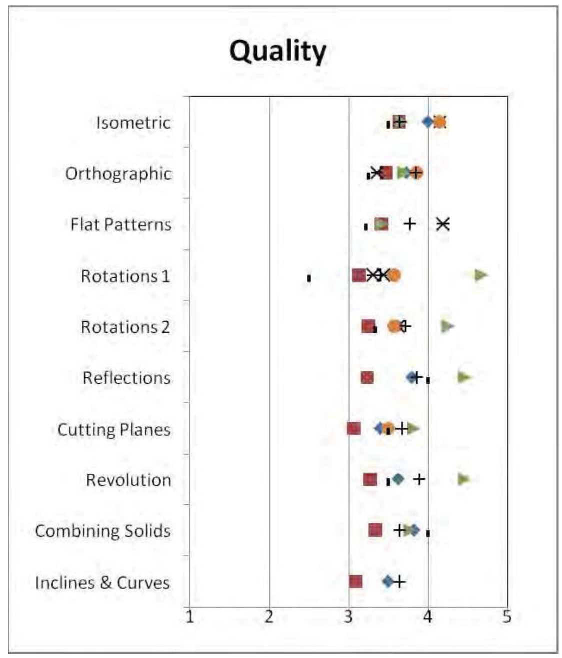

Figure 2: Average student responses to module evaluation Question 1: Module Quality. Each symbol represents a different training of the curriculum.

The average student responses to Question 2, the length of the module is shown in Figure 3. A score of two indicates the length of the module is the appropriate length, a score less than two indicates the module was too short, and a score above two indicates the module was too long. The lengths of the modules were appropriate for most of the students at all institutions as shown in Figure 3. As shown in Table 1, the modules on Orthographic Drawings, Single Axis Rotations, and Reflections and Symmetry had the highest score, 2.3, indicating students felt these modules were slightly too long.

Table 1: Student responses to module evaluation questions 1-3, averaged over all institutions. Standard deviations are shown in parentheses.

	Quality (5 pt. scale)	Length (3 pt scale)	Level (3 pt scale)
Isometric	3.8 (0.70)	2.1 (0.41)	2.0 (0.41)
Orthographic	3.5 (0.76)	2.3 (0.52)	2.0 (0.40)
Flat Patterns	3.5 (0.75)	2.1 (0.39)	1.9 (0.38)
Single Axis Rotations	3.3 (0.95)	2.3 (0.52)	2.1 (0.33)
Multi Axis Rotations	3.6 (0.90)	2.1 (0.35)	2.1 (0.27)
Reflections & Symmetry	3.9 (0.83)	2.3 (0.47)	2.0 (0.28)
Cutting Planes & Cross-sections	3.5 (0.75)	2.0 (0.28)	2.0 (0.39)
Revolution	3.6 (0.84)	2.0 (0.28)	1.9 (0.39)
Combining Solids	3.7 (0.77)	2.0 (0.30)	1.9 (0.31)
Inclines & Curves	3.4 (0.80)	2.1 (0.37)	2.0 (0.37)

The difficulty of the modules was assessed by Question 3: For my learning purposes, the overall level of this module was: 1) too simple for my needs, 2) appropriate to my needs, or 3) too advanced for my needs. As shown in Figure 4, the average student responses ranged from 1.7 to 3, with most responses near 2. When responses for this question was averaged over all of the institutions, all the modules fell between 1.9 and 2.1, shown in Table 1 above, indicating the modules were the appropriate level for these students.

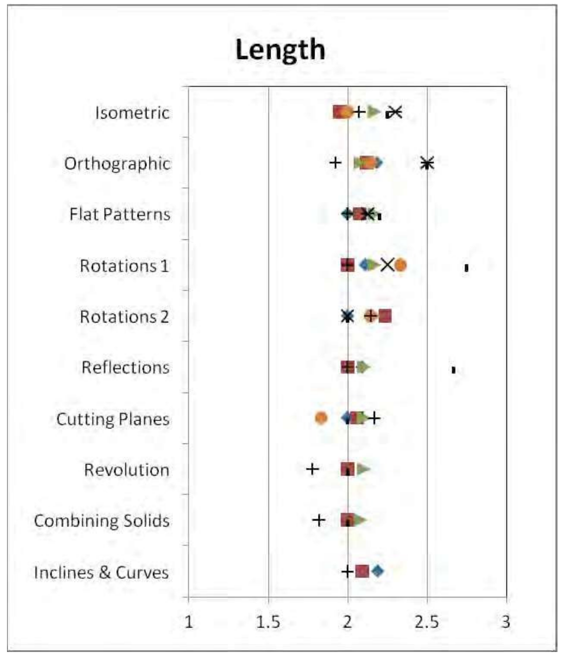

Figure 3: Average student responses to module evaluation Question 2: Module Length. 1=too short, 2=appropriate, 3=too long.

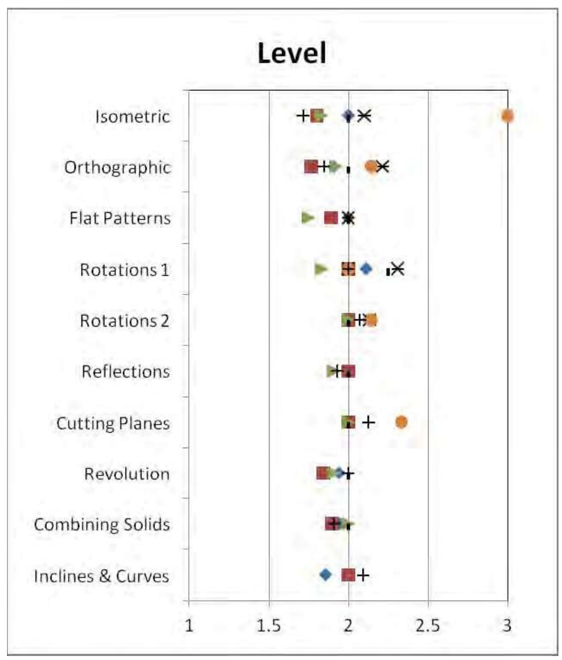

Figure 4: Average student responses to module evaluation Question 3: Level. 1=too simple, 2=appropriate, 3=too advanced.

It is interesting to note that the group of students that rated the quality of the module on

Rotations about a Single Axis between fair and good, rated the length of the module as being too long. As their responses to the overall level indicate, these students appeared to have some difficulty with this topic. These same students found the next module, Rotations about Two or More Axes to be better in quality, more appropriate in length, and at a more appropriate level for their needs.

To help identify which instruction tools help students learn and understand the material, students were asked on Question 4 if each tool (or component of the training) was beneficial to their understanding of the material. Scores could range from 1: Strongly Disagree to 4: Strongly Agree, or Not Applicable. Note this is a 4 point scale, so there is not a neutral response. Average student responses for a) Instruction, b) Software, and c) Workbook are shown in Figures 5-7. The module on Inclined and Curved Surfaces consisted of a short lecture and a handout of sketching exercises. Since this module did not have a software or workbook component, it is not included in Figures 6 and 7.

As shown in Figure 5, the average student responses indicate that they agree that instruction is beneficial to their understanding of the material. This was true whether or not the instructor chose to use the Michigan Tech lecture materials or relied on the workbook and software to introduce the students to the materials.

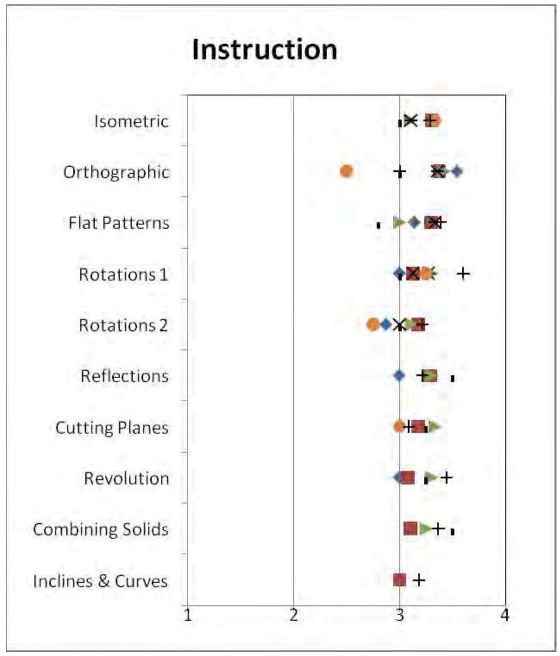

Figure 5: Average student responses to module evaluation Question 4a: Instruction was beneficial to my understanding of material.

It should also be noted that some of the trainings were led by instructors who had used the course materials before, while some were led by instructors using the materials for the first time. This could explain some of the variability in the student responses.

The average student responses to the 3-D spatial software are shown in Figure 6. Students agree or strongly agree that the software is beneficial to their understanding of the material. It appears to be especially useful for the modules on Rotations, Cutting Planes, and Combining Solids.

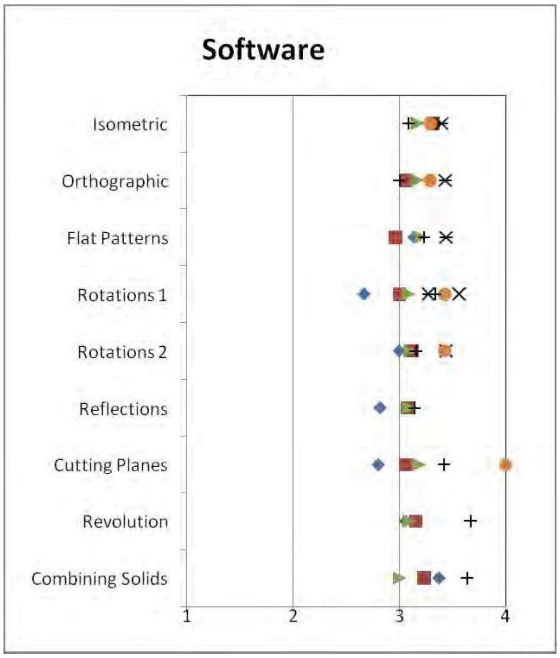

Figure 6: Average student responses to module evaluation Question 4b: 3-D spatial software was beneficial to my understanding of material.

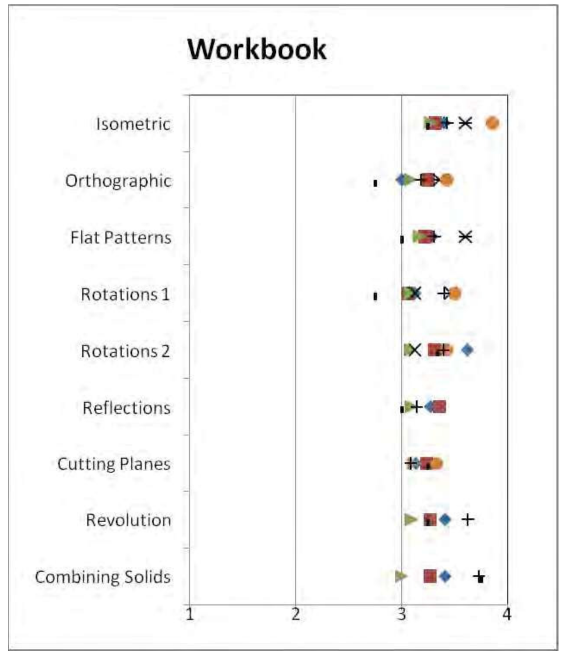

Figure 7: Average student responses to module evaluation Question 4c: Workbook was beneficial to my understanding of material.

As shown in Figure 7, students consistently report the workbook problems are beneficial to their understanding of the material, indicated by scores ranging from 3-agree to 4-strongly agree. The module on Isometrics received the highest rating for how beneficial the workbook was to their learning.

It appears that a number of students were unsure of what the VIZ website and manipulatives referred to since students rated these tools for modules for which they were not used. Therefore the student responses for the helpfulness of these tools are not reported in this study.

There were a wide variety of responses on the evaluation instrument when asking students to suggest improvements for each module. For some modules, approximately equal numbers of students reported needing either more or less instruction and examples: this could be interpreted as meaning the level of instruction was appropriate for the average student in the class. For example, suggestions for improving the Isometric Drawing module included these statements: "The range of difficulty was vast. It was easy at the beginning then it got harder, and I struggled at the end," "Make it more tricky," and "Separate into groups based on understanding." This last statement seems to exemplify the range of development and ease of development of spatial skills for the students taking the trainings. Students did suggest more examples and explanation were needed on two of the modules, however, these suggestions seemed to be instructor dependent.

Some students stated some difficulty with clarity in the workbook; they thought it was difficult to see where the cutting planes went through the objects in the Cutting Planes module, and some thought the objects in the Combining Solids workbook pages were confusing. For many of the modules, the blocks will help overcome difficulties with visualization, however, the blocks are not helpful for the Cutting Planes, Combining Solids, and Revolution modules. The statements about lack of clarity in the workbook for the Cutting Planes and Combining Solids modules may be directly related to the fact that these modules rely most heavily on visualization skills.

The only suggestion for improving the workbook software related to some students having difficulty where they were asked to use the mouse to draw an isometric sketch in the first module.

Students were asked to report strategies that were most helpful in completing the modules. Using the blocks provided in class seemed key in drawing isometric and orthographic views, rotating objects, and drawing reflections of objects. Discussions and working with others was mentioned as being important most often for the first two modules, Isometrics and Orthographics, however, this was mentioned as either a strategy or as a request for more group work for all of the modules except the Cutting Planes module. The right hand rule was helpful for both Rotation modules. When drawing or identifying isometric views of objects from different corners, students reported that it helped to rotate the book so the view point faced them. For flat patterns, counting and matching folds helped identify correct patterns. Students identified cross sections by drawing the cutting planes on the shape. Here, they also mentioned visualization as being key to identifying the correct cross section. To find solids of revolution, students applied what they learned in the Reflections module: they drew an axis of revolution and then reflected the shape over that axis to help them visualize what the revolved shape looked like. They identified visualization as being a useful strategy for combining solids.

V. Instructor Evaluations

Five of the instructors involved in the project completed the instructor module evaluations which were nearly identical to the student module evaluations. The instructors at Michigan Tech did not complete the evaluations as the course materials, with the exception of the VIZ website, were developed at Michigan Tech.

All of the instructors rated the length and level of all modules as appropriate, with the exception that one instructor felt the module on Rotations about Two or More Axes was both too difficult and too long. They rated the quality of the modules that corresponded to the first four modules and modules 6 and 7 in the workbook as either very good or excellent. The ratings of the quality of the Rotations about Two or More Axes, Surfaces and Solids of Revolution and Combining Solids modules were more varied, they received ratings of both good, very good, and excellent (compared to the very good and excellent ratings of the other modules).

When rating what was beneficial to their instruction of the material, a value of 3 indicates the instructor agreed the tool was beneficial and a value of 4 indicates strong agreement that the tool/material was beneficial. The instructors were almost unanimous in strongly agreeing the workbook and workbook software were beneficial to their instruction for the second through seventh modules (average ratings of 3.8 to 4 out of 4). The workbook software was given an average rating of 3.67 for the Isometrics module while the workbook was given an average rating of 3.8 for this module. The ratings for the workbook software and workbook for Surfaces and Solids of Revolution and Combining Solids modules ranged from 3.5 to 3.67 on a 4-point scale. Average ratings for how beneficial the lecture materials were to their instruction ranged from 3 to 3.2 for each module. Manipulatives such as blocks were used by almost all the instructors for the modules on Isometrics, Orthographics, and Rotations and were found to be strongly beneficial to their instruction of the material.

Most instructors suggested improvements to the first module: Isometric Drawings. This module has students draw isometric views of coded plans from different viewpoints. For example, the module may ask students to draw an isometric view of the coded plan shown below from corner A. Instructors thought this was a big step for the students' first exposure to drawing isometric pictorials and suggested always having the students draw the pictorial from the same corner of the coded plan, corner C in the figure below.

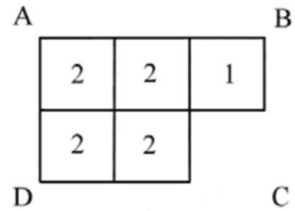

Figure 8: Example coded plan from the isometric projection module

One instructor felt the students who struggled with the Orthographic Drawings module struggled mostly with drawing the isometric pictorial from the orthographic views. It was suggested that adding exercises that built from simple to more complex would help the struggling students.

Suggestions for the Rotations modules included having a large manipulative (object) to show Rotations about a Single Axis and then using the same large object in the Rotations about Two or More Axes module. Some instructors used a manipulative in addition to the blocks for the Rotations modules. They either constructed a 3-D coordinate system out of something such as wooden dowels or drew a 2-D coordinate system with the 3rd axis projecting perpendicularly from the origin on a handout. One instructor also included coded plans for the objects shown in the Rotations lecture slides.

Instructors suggested specific improvements for two other modules and stated that using more tactile elements and adding hands-on activities in addition to the workbook exercises would be beneficial for all modules. It was suggested to use physical objects that could be cut in different directions, such as a pool noodle, to demonstrate how cross sections differ with different cutting planes. The workbook exercises for the Surfaces and Solids of Revolution module are entirely multiple choice. It was suggested that adding hints for this module could reduce the amount of guessing on the part of the students. For all modules, asking students to share strategies in a class discussion could help students.

VI. Conclusion

Based on the student evaluations summarized above, it appears the modules in the Michigan Tech course are of high quality and an appropriate length and level of difficulty for students taking the curriculum, whether students are trained on all of the modules or only some of the modules. Two things seem key in helping students successfully master the material: providing blocks and other manipulatives and allowing and encouraging students to work together.

The instructors using the materials also rate the modules' quality, length, and appropriateness highly. They feel the workbook and workbook software are most beneficial in teaching the material, and that every effort should be made to provide students with manipulatives such as blocks, a 3-D coordinate system, or other tactile elements.

In conclusion, both the student and instructor module evaluations indicate the material can be successfully implemented in a variety of methods with a variety of audiences.

VII. References

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