# Learning Style Based Innovations to Improve Retention of Female Engineering Students in the Synthesis Coalition

Alice M. Agogino
Director, Synthesis Coalition
3112 Etcheverry Hall
University of California at Berkeley, CA 94720
aagogino@euler.me.berkeley.edu

Sherry Hsi
Science & Mathematics Education Group
4533 Tolman Hall
University of California at Berkeley, CA 94720
hsi@garnet.berkeley.edu

## Abstract

This paper describes the use of integrative multimedia courseware designed to scaffold student learning and accommodate learning style differences. Synthesis courseware aimed at improving the retention of under-represented engineers has been further designed to work effectively in a range of educational settings, including classroom, high-tech small study groups and self-paced individualized learning. As an example, this paper focuses on the Spatial Reasoning project aimed at improving the retention of female engineering students through scaffolding students in spatial reasoning. The courseware described in this paper can be found on the NEEDS (National Engineering Delivery System; http://needs.org/) database of engineering courseware.

## Retention Programs of the Synthesis Coalition

The Synthesis Coalition (California Polytechnic University at San Luis Obispo, Cornell, Hampton, Iowa State, Southern, Stanford, Tuskegee, and University of California at Berkeley) is part of a national effort to improve undergraduate engineering education and improve the retention of under-represented engineers. Both of these goals are being achieved through the use of educational multimedia in a way that takes advantage of the diversity of learning styles of our undergraduate students. Our courseware is integrated with classroom and laboratory techniques that build on the Kolb model [1] of experiential learning, making use of case studies of engineering design [2], hands-on activities [3], experimentation and simulation along with engineering fundamentals.

Synthesis has developed a number of strategies for improving the retention of under-represented engineers, such as providing on-line role modes on the World Wide Web, courseware on the role of women and African-Americans in the history of technology, tutorial courseware for self-paced learning, and undergraduate research experiences. In a study whose results are now justifying our choice of curricular synthesis as our conceptual and pedagogical basis, Seymour and Hewitt [4 : 57] concluded that, "Criticism of faculty pedagogy contributed to 1/3 of all switching decisions, and was the third most commonly-mentioned factor in such decisions." Synthesis curricula and pedagogical techniques address many of the problems historically associated with poor retention in engineering (Table 1).

**Table 1:** Synthesis approach to retention.

| Cause of Retention Problem | Synthesis Curricular Solution |
|---|---|
| lack of early exposure to engineering | synthesis in freshman/sophomore courses |
| narrow analytical focus | exposure to the complete cycle of the engineering process |
| lack of excitement | real world applications, multimedia |
| lack of relevance | case study approaches emphasizing societal factors |
| teach to single learning style | emphasis on complete cycle of styles |

Perhaps the most successful are our programs aimed at "gateway" courses where the attrition rate has historically been the highest. High-technology learning centers [5] bring courseware and small study groups together to create nurturing support and learning environments for under-represented engineers taking these gateway courses. Much of this work in small study groups is based on early work by Uri Treisman [6] in which participating minority students earned on the average one letter grade higher in their math and science courses than nonparticipating minority students and they exceeded the average grades achieved by white students in the same courses. The addition of instructional software to this approach allows even more flexibility in tailoring tutorial sessions to each individual student's needs. An example of this approach, integrating the small study group concept with courseware geared for learning style differences, applied to freshman/ sophomore students is described in the rest of this paper.

## Example: Scaffolding Female Students in Spatial Reasoning

In many engineering disciplines spatial reasoning and visualization contribute to a student's success in introductory design classes. Unfortunately, the spatial skills and experiences of incoming engineering students are quire varied with some indications of gender differences [8]. In Fall 1991, in a large freshman/sophomore design class UC Berkeley 25% of the female students received a grade of D or F for the semester - - a much higher failure rate than in past semesters. As this was the first semester that the class had used CAD (computer-aided design) rather than hand drafting, we suspected that gender differences in spatial skills and computer experience might be the cause of the high failure rate for the female students. A study of learning style differences was initiated with faculty from both the College of engineering and the School of Education at UC Berkeley [9]. We were joined by collaborating faculty at other schools in the Synthesis Coalition. This results of the study led to the design of spatial reasoning instruction including hands-on activities, innovative computer courseware, and problem-solving assessments. Pre-and post-tests were given to over 500 students. Student responses to small study Saturday workshops illustrate the nature of the exposure and provide representative student feedback. A summary of a more rigorous statistical analysis of pre- and post-testing during one semester of the project is provided in the Conclusions section of this paper.

### Saturday Workshops

During the Spring of 1994, Professor Alice Agogino (Mechanical Engineering, U.C. Berkeley) invited her E28 students to attend a special workshop that she organized to help students improve their spatial reasoning skills. Thirteen students attended, of which eleven were female and two were male. Attendance was voluntary and no emphasis was placed on encouraging female students to attend. Nevertheless, almost all of the female students in the class attended, indicating a gender-related lack of confidence in spatial reasoning. The workshop lasted approximately two hours with the following schedule:

- Presentation by Professor Agogino
- Hand drawing exercises
- Lego exercises
- Blockstacking software to assess spatial skills

- Display Object software to develop spatial skills

The presentation was an introductory talk given by Professor Agogino, which explained the purpose and scope of the workshop, as well as some of the theory involved. In the hand drawings exercise the students had to draw the different views (front, top, side, orthogonal) of various objects. Blockstacking and Display Object are software programs designed by Synthesis. The lego block exercises provided concrete examples of shapes that are covered in the Blockstacking quizzes and Display Object software. Students were allowed to work in small groups or as individuals. Most of the tutors were female graduate students.

**Blockstacking**

In Blockstacking the students take a series of quizzes that are designed to assess the spatial skills of the student in a non-threatening manner. Students are given the opportunity to use the Lego blocks to visualize the exercises better in three dimensions. They are given side and front views and are asked to construct top views, showing the minimum and maximum (Fig. 1) blocks configurations. The minimum blocks configuration is the object which contains the minimum number of blocks while still remaining consistent with the front and side views. The maximum blocks configuration is that which contains the maximum number of blocks. The instructor and tutors use the results to decide how best to approach tutoring the student. A "rap" version was created by one undergraduate student in fun and it has been popular with our freshman and pre-college outreach programs.

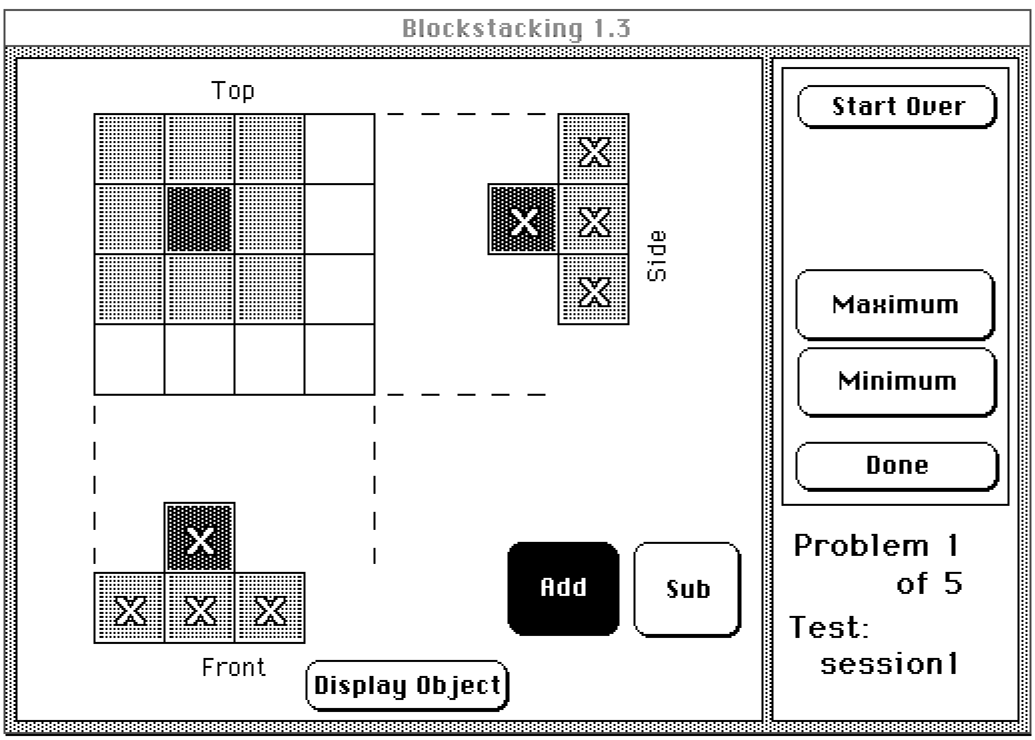


**Fig. 1:** A maximum blocks configuration in the Blockstacking assessment software.

**Display Object**

Display Object [9] gives the students the opportunity to rotate objects freely about different axes, which makes it an excellent tool for visualization (Fig. 2). It has an easy to use interface that allows the student to work in virtual objects through standard and arbitrary three dimensional rotations. The objects that can viewed include those used in the hand drawing, Lego, and Blockstacking exercises.

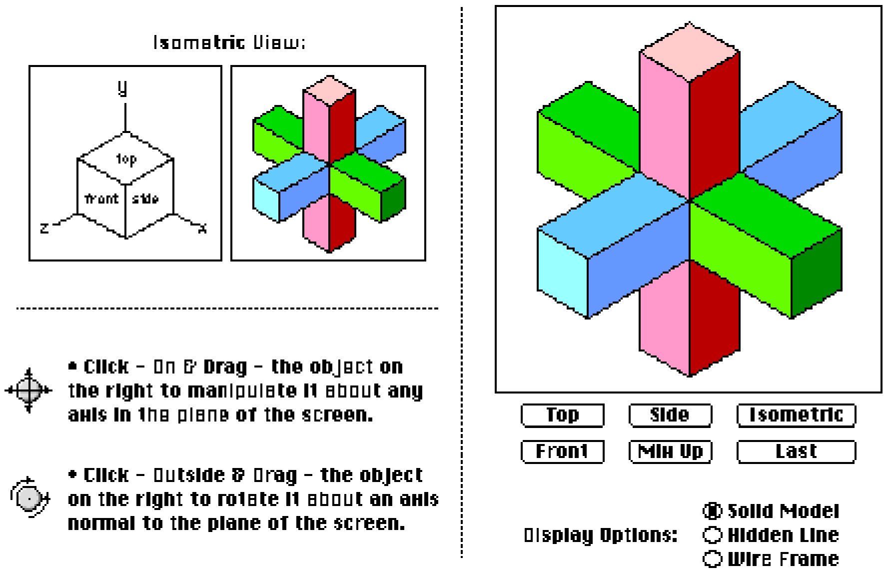


**Fig. 2:** Display Object screen in "display" mode [9].

### Student Interviews

Several students were interviewed and asked what they liked best about the workshop. These are representative responses:

*. . . Display Object. You could rotate [the objects] around and see different sides -- the top view and the side view. It was really, really helpful to me. It was helpful for me because I had a lot of trouble with spatial reasoning and picturing 3-D objects from a flat surface...*"

*I think that more high-tech tools in undergraduate education would really help and improve students' scores because when you make something fun for a student they get more involved. . . . they would actually be excited and they'd want to learn. So I think that if they show you how a certain particular class can be fun, more students are going to want to learn it.*

### Student Responses

All students were given a survey after the workshop. All of the students credited the workshop as either "helping" or "helping a lot" with "some better" or "much better" improvement in level of confidence as a result of the session.

The students were asked to rank the elements of the workshop in order of importance. The students indicated the hand drawings portion of the workshop to be the most valuable. Placing second and third were the computer applications, Display Object and Blockstacking. The students indicated that the computer applications were more valuable than the lego exercises, presentation, and even the help of the teaching assistants and instructor.

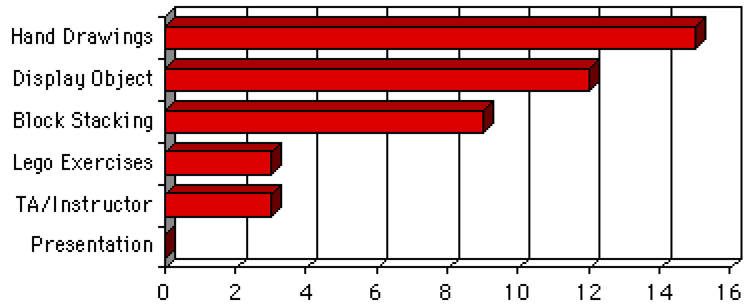


**Fig. 3:** Students ranking of elements of workshop (higher is better).

## Conclusions

Over 500 students in an introductory engineering course have participated in our spatial reasoning instruction. Overall students made significant progress in spatial reasoning. During one semester with a class of 150 students pre- and post-tests were administered to quantify this effect.

Pre-assessment results indicate incoming engineering students demonstrate a wide range of abilities in spatial reasoning. At the beginning of the semester, males had more experience in orthographic drawing ($t = 2.43$, $p = .016$) and had better spatial problem solving performance on the engineering items ( $t = 2.2$, $p < .02$). Women also showed a tendency to do worse on generating isometric views ($t = 1.86$, $p = .06$). Gender differences at the beginning of the semester were also found at other universities who administered the same pre-assessment. (orthographic: p = .01, isometric: p = 0.12).

After the spatial reasoning intervention and at the end of the course, there were no gender differences in spatial reasoning ability *(post: $t = .76$ $p = .45$ ).* Gender differences in ability at the beginning of the course appear to be ameliorated by the course and our short spatial reasoning tutorial. Consistent with literature on improvement with spatial training, women also tended to do better than males on the post assessment on traditional items when given more experience*($t= -1.79$ $p=.07$)* .

Although males and females differed in the ability to generate orthographic projections on the pretest, these differences disappeared on the post-test. We recommend that instruction should include spatial strategies as a part of the mix of approaches for engineering problem solving. Student feedback from the workshops indicate that the small study group concept integrated with instructional software is an effective framework for providing in-depth tutoring on spatial strategies.

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