Visual Learning in Science and Engineering

__Visual Learning__ is the use of graphics, images and animations
to enable and enhance learning in science and engineering

Background of Workshop
Visual learning was the focus of one track of the ACM SIGGRAPH/Eurographics Workshop on Computer Graphics Education held June 2-5, 2004, in Hangzhou, China. Many conferences have been organized by Zhejiang University in Hangzhou, but this was the first specifically dedicated to education. This track was a follow-up to the ACM SIGGRAPH/Eurographics Campfire on Visual Learning held in 2002 in Snowbird, Utah. (See http://www.siggraph.org/education/vl/vl.htm). Participants represented engineering, computer science, information science, web design, instructional design, and fine arts. A full report will follow after these ideas are discussed at related conferences this year.

The goals of the Hangzhou visual learning workshop were to:

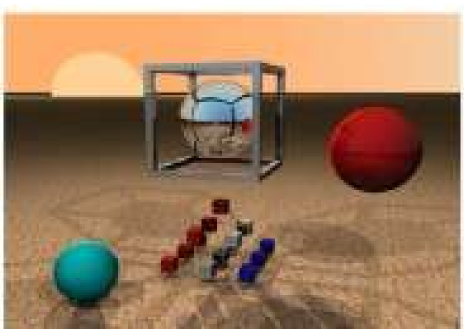
refine the ideas from the 2002 campfire
merge these ideas with new insights, especially those from the new Chinese participation
recommend implementation guidelines for visual learning in science and engineering.

"Visuals" include symbols, animations, and even body language and gestures. Visuals may further enhance learning when combined with auditory and other sensory functions as an integrated learning experience. This workshop focused on computer-graphics based images and animations.

Findings
The discussion was lively; and the following key points emerged:
1. Students must understand the visuals if learning is to occur.
These include visuals the students *create* as they learn, and visuals *viewed* as the instructor illustrates concepts. Two examples illustrate this point:

Use examples from science and engineering.
In order for science and engineering students to understand the images, they may need to see the value of them, by having the examples drawn from science and engineering.

Students at the Dalian Maritime University in China learn complex navigational skills through immersive virtual reality created by the students (right).

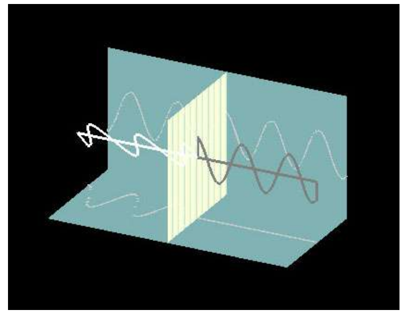


Creating simple computer graphics can be a powerful strategy for learning basic principles of computer science.

Students at Clemson University create images with a raytracer. They can tell immediately if the image is accurate, and can easily correct their mistakes because the images point back to the underlying problem. Both correct images and mistakes enable learning. This image was produced by sophomore student S. Duckworth (left).

2. Students can learn science effectively by creating their own visuals
When students create visuals as part of learning science and engineering, they must work with fundamental principles in the field and must learn how these principles function as part of larger systems. Creating images is an active learning technique, and sharing ideas through visuals makes the student understand principles well enough to communicate them to others. We can see "visualizing to learn" as a parallel to the established "writing to learn" education process. The graphics capabilities of modern computers support many graphical tools, both simple and complex, that students can use in this work. However, textbooks and coursework in science and engineering do not yet include student visualizations as standard projects, so professors in science and engineering now need to learn

how to include student visualization activities in their courses. This image is a visualization of polarized light by Virginia Muncy.



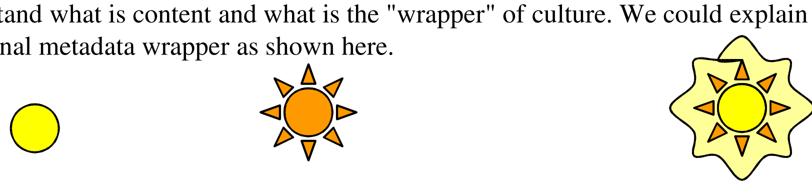
3. Strong, diverse opinions exist regarding how much students need to know about design principles. Some participants felt that science and engineering students need to know design principles so they can create "good" visuals. This raised the question about which design principles students need to learn as well as where the knowledge of design needed to be on the continuum from competency to fluency. An opposing point of view held that students learn from images, whether they represent good or bad design. As Dr. James Foley asked a week later at the VRCAI and Graphite Conferences in Singapore, "How do we know when a graphic is 'good enough'?"

4. Cultural understanding of images is important.

The challenges are to know and understand the cultural differences and distinguish which differences are critical for understanding the concepts. We think the best option is to retain and embrace cultural differences. Yet we want to be understood.

This image illustrates Virtual Dunhuang Cave Art. The image is from a virtual environment of one of the caves at Dunhuang, China. The image is by Bernd Lutz, Fraunhofer Institute, Germany.

One solution for understanding content without losing or being confused by the cultural differences is to try to understand what is content and what is the "wrapper" of culture. We could explain cultural concepts with an additional metadata wrapper as shown here.



Content | Culture as a wrapper | Content and culture connected, and a metadata wrapper that explains the cultural concepts

5. Verifying proficiency in creating and understanding visuals can guide curriculum and assist employment
In Europe, there is now a Computer Driver's License that verifies someone has basic computer skills. There is a test to get this license, and it may become a criteria for gaining employment. In the sciences, a similar “visual driver's license” might be based on the following triad:

- knowledge of the content or message being presented
- skills needed to understand the visuals
- skills needed to produce the visuals

The "license" certifies a minimum set of skills, and there was interest in defining these minimal skills.

6. Numerous strategies can address the needs for visual learning in science and engineering
Approaches will vary by country, culture, and type of college, university or other educational source. Traditional curricular approaches might be to:

- require an existing visual learning course
- modify an existing course to include visual learning elements
- create a new required course
- create a new elective course

Courses need not be credit-bearing. A student’s goal may be to acquire competency rather than complete graduation requirements. Other issues include cross-cultural support, including multi-language issues, and technical multi-platform issues, There was a suggestion that ACM SIGGRAPH sponsor online modules or a course to supplement programs worldwide. Regardless of strategy used, measures of success and evaluations of effectiveness must be conducted and communicated.

Attendees included Cui Xie, Joan Huntley, Tim Davis, Zhigeng Pan, Haixu Xi, Xun Wang, Ruwei Yun, Colleen Case, José Teixeira, Chunyu Li, Zhangye Wang, Jacki Morie, Marla Schweppe, Judy Brown, Bernd Lutz, Guanping Zheng, Peter Giles, Peter Morse, Frank Hanisch, Qin Aihong, and Xubo Yang.

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