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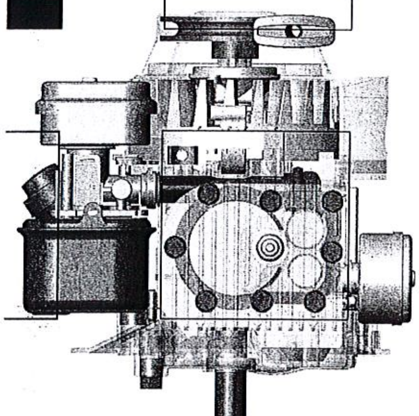
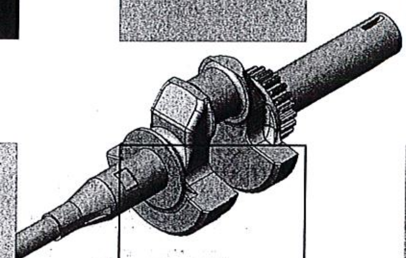
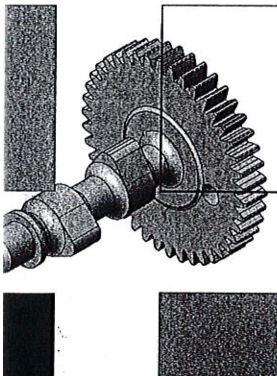
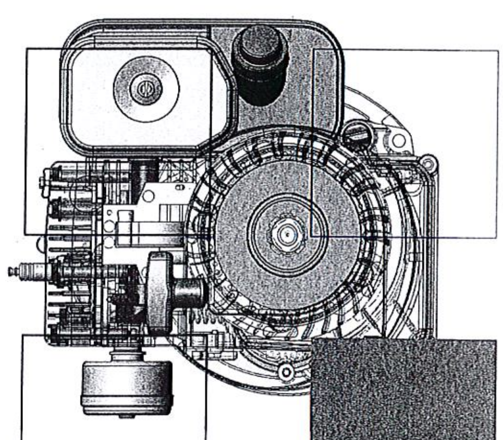
THE ENGINEERING DESIGN GRAPHICS Journal









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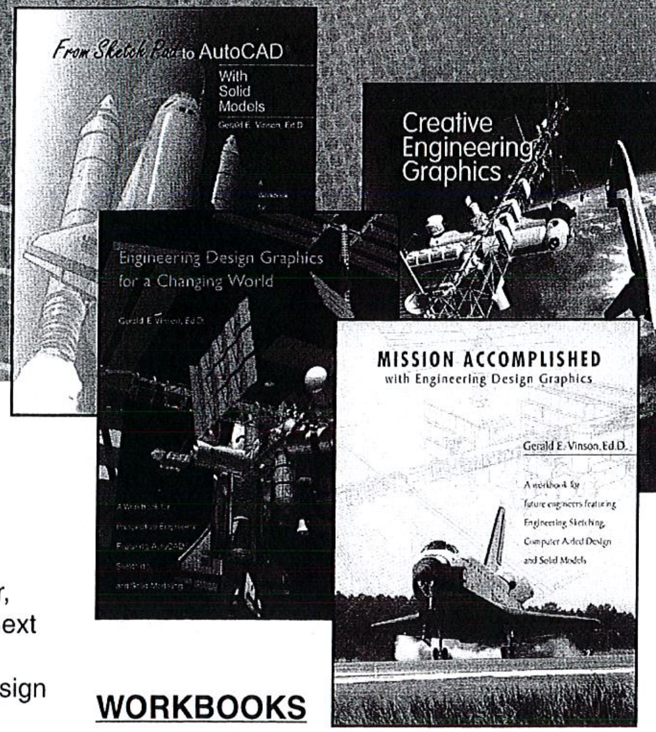

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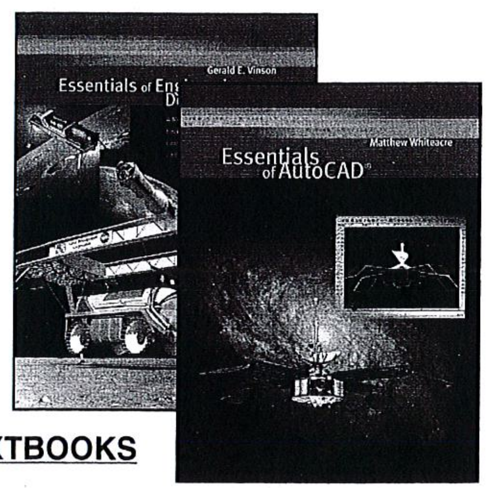

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The Engineering Design Graphics Journal is the official publication of the Engineering Design Graphics Division of ASEE. The scope of the Journal is devoted to the advancement of engineering design graphics, computer graphics, and subjects related to engineering design graphics in an effort to 1) encourage research, development, and refinement of theory and applications of engineering design graphics for understanding and practice, 2) encourage teachers of engineering design graphics to experiment with and test appropriate teaching techniques and topics to further improve the quality and modernization of instruction and courses, and 3) stimulate the preparation of articles and papers on topics of interest to the membership. Acceptance of submitted papers will depend upon the results of a review process and upon the judgement of the editors as to the importance of the papers to the membership. Papers must be written in a style appropriate for archival purposes.

Cover graphics contributed by Ted Branoff

ISSN 0046 - 2012

[From the Editor]

Dear Members:

The three articles in this issue reflect themes common to the Engineering Design Graphics Journal: a selection of graphics technology, techniques for the use of this technology, and issues with the integration of technology into the classroom. While graphics technology has been part and parcel of this Division since its inception, the challenges of effective use and integration have not abated.

The first article by Smith takes a look at the last theme: the integration of technology into the classroom. While stereoscopic viewing technology has been with us since the Victorian era, evolving technology has allowed instructors to set up low cost, full-color, dynamic viewing systems in their classrooms. As is often the case, the march of technology has preceded the research on its effectiveness in the classroom. Smith looks at a number of important pedagogical and integration issues, including psychophysical issues of discomfort from using the viewing apparatus.

The second article by Birchman and Flaherty provide an excellent example of how research and practice can come together. The article discusses the ways animation tools such as Flash can be used to support instruction. In addition to providing examples of practice, they also provide a research basis for their instructional effectiveness.

Finally, Okudan picks up on a well-established line of research looking at how to select a solid modeling software package. The article uses both past and current research to help refine a set of protocols that can be used by members of this Division in their quest to acquire the best possible instructional tools for their classrooms.

Please review the candidate slate printed in this Journal issue and vote when you receive your ballot in the mail. Strong participation in election process of the Division is an important hallmark of the EDGD. Take a look at the pictures from the mid-year meeting in Williamsburg, VA and see how much fun folks are having. Join us and become part of the fun in Orlando!

Eric N Wiebe

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Message from the Chair

Holly K. Ault
Worchester Polytechnic Institute

The ASEE's Engineering Design Graphics Division's 59th Annual Mid-year Meeting was held in Williamsburg, Virginia on November 21-23, 2004. Over one hundred members and friends attended the meeting and enjoyed the benefits of exchanging ideas on teaching graphics and design, networking with our colleagues, and interacting with software vendors and publishers. And of course, we also enjoyed the hospitality of the historic village of Williamsburg, dining with authentic colonial fare, and discussions of politics and household affairs with patriots and loyalists alike.

The opportunity to participate in these conferences is not the only benefit of membership in the EDG Division, but it is certainly one of the most often cited as reason for joining the Division. Our membership is drawn from engineering and technical universities and community/junior colleges throughout this country and from abroad. The Division promotes teaching, research, discussion, and communication in all forms and applications of technical graphics. Other benefits include our journal, which you are reading now. The EDG Journal provides a venue for refereed publication of your research. We sponsor the National Student Design Competition at the ASEE Annual Conference.

Not only does membership in our division provide benefits, but it also comes with some responsibilities. According to the dictionary, a member is "one that belongs to a group or organization", and we think of our membership in the Division in that sense. However, we also refer to members as specific structural units or body parts. Structural units function to support and strengthen the unit to which they belong. Body parts likewise have a specific and useful function. Likewise, members in a strong and healthy organization are expected to contribute to the work and mission of the group. What can you do, as a contributing member of the division?

What can you do, as a contributing member of the division?

First, spread the word! Recruit! We need to include all graphics educators in our organization. If you are reading this message and enjoying our journal, but are not a member, I hope you will be encouraged to join. If you are already a member, encourage your colleagues to join. Plan now to bring a colleague to our next mid-year meeting in Fort Lauderdale, Florida, on December 3-6, 2005. If you have contacts at other universities or local community colleges, invite them to one of our meetings, or share a copy of our journal with them. Even if their budgets and teaching schedules limit their conference attendance, they can still benefit from the exchange of ideas through publications and our website.

Second, contribute! To the journal, to conferences, or to our zones pages (contact Alice Scales, Alice_Scales@ncsu.edu). I encourage all of you to submit papers to the journal, and incorporate the design competition into your freshman graphics course. See the contest website for more information about the Student Design Competition (http://www.rpi.edu/~baxted/glider/glider.htm).

And finally, be active in service to the division. If you are interested in participating in the work of any of the committees (Membership, Liaison, Professional and Technical, Publications, Programs, Zones), please contact the appropriate committee director, listed on our website (http://www.east.asu.edu/edgj/edgd/). We are also still looking for people to help with the upcoming conferences. Our next mid-year meeting will be held in Ft. Lauderdale, Florida. Wouldn't you like to be involved? Ron Paré, Mike Stewart and Kathy Holliday-Darr would appreciate your help.

As American Express reminds us, "membership has its benefits," but also its responsibilities. I hope to see you all add your support to make ours a viable and healthy division.

[Calendar of Events]

Division: http://www.east.asu.edu/edgj/edgd

2005 Annual ASEE Conference
Portland, Oregon
June 12-15, 2005
Program Chair: Ron Pare

60th Mid-Year Technical Conference
Fort Lauderdale, Florida
December 3-6, 2005
Program Chair: Michael Stewart

2006 Annual ASEE Conference
Chicago, Illinois
June 18-21, 2006
Program Chair: Frank Croft

2007 Annual ASEE Conference
Honolulu, Hawaii
June 24-27, 2007
Program Chair: Michael Stewart

Oppenheimer Endowment Fund

Individual EDG member donations are being solicited until a target corpus is met. Several donations and pledges in the range of $50-$250 have already been received. If you would like to donate, write your check made out to "ASEE EDG Division," write a note for "Oppenheimer Endowment," and send it to:

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Chair, Oppenheimer Endowment Fund Committee
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University of Texas at Austin
Austin, Texas 78712

Integrating Computer-generated Stereoscopic Models Into An Introductory Design Course

Shana Smith
Iowa State University

Abstract

Stereoscopic technology has been successfully used in several learning and education environments. However, uses for and the effectiveness of computer-generated stereo models in design and graphics education still have not been extensively explored, especially in a large classroom setting. This pilot study examines the applications and potential of computer-generated stereo models in design and graphics courses in a large classroom setting. Computer-generated stereo models were displayed and manipulated in the classroom to help students acquire 3-D concepts. A survey was developed to both quantitatively and qualitatively measure student perceptions with and without using the stereoscopic systems. The study survey shows that the effectiveness of integrating computer-generated stereo models in design courses is not only affected by model image quality, but also by physical reactions to stereoscopy (e.g., some students felt dizzy or could not visualize stereoscopic views). Since model image quality is greatly influenced by the stereoscopic system used, further study is needed for determining the most cost-effective stereoscopic system for general design and graphics classroom use. In addition, pedagogical factors for best use the models to promote learning also need to be investigated.

Introduction

With the advance of computer technology, graphics technology has progressed from manual drafting to computer-aided design. The objectives of graphics education have also changed accordingly. Increased emphasis has been placed on design, problem-solving, presentation, and communication skills. However, three-dimensional (3-D) spatial visualization ability is the core requirement for successfully developing those skills.

Three-dimensional visualization ability, to a great extent, determines students' performance in design and technical graphics courses. Prior research has shown that student 3-D visualization ability greatly influences students' future career success in science, engineering, and technology (McKim, 1980; Norman, 1994; Pleck, McGrath, Bertoline, Bowers & Sadowski, 1990). Students without sufficient 3-D perception ability may become frustrated and drop out of CAD programs, or they may be encouraged to not major in CAD programs. If students can improve and gain confidence in their 3-D visualization skills, they will enjoy CAD instruction more and become more engaged.

Prior research shows that visualization is a skill that can be learned, developed, and improved with proper instruction and methods (Gagon, 1985; McKim, 1980). Thus, in order to help students remain in and succeed in CAD programs and to succeed in their future careers, it is essential to find the most effective method to deliver graphics concepts and to enhance student 3-D spatial visualization skills.

One way to enhance students' ability to visualize 3-D objects is to make their experience of the objects, while learning, as realistic as possible. However, in general, it is very difficult to clearly describe to students a 3-D object and the spatial relationships between object components, without using a physical mockup. Physical mockups take a significant amount of time to construct, especially for more-complex objects. As a result, graphics educators have been using 3-D CAD tools to help students understand spatial relationships between objects. However, CAD tools only allow students to examine 3-D models from outside flat computer monitors. In other words, the models and the viewers are in different realms. Using traditional CAD tools, students cannot view models with natural stereoscopic vision.

Stereoscopic technology simulates the natural vision process by using computer technology to create right-eye and left-eye images of a given 3-D object or scene. The brain integrates the information from these two perspectives to create the perception of 3-D space. Thus, stereoscopic technology creates the illusion that on-screen objects have depth and presence beyond the flat image projected onto the screen. Viewers can perceive distance and spatial relationships between different object components more realistically and accurately than with conventional visualization tools (e.g., traditional CAD tools). In industry, several major companies have integrated stereoscopic technology into their design processes to improve product quality, for example, Ford, Motorola, Harley Davidson, BMW, and GE (StereoGraphics Corp., 1999).

Prices for stereoscopic systems can vary from one dollar to half million dollars. The capacity of the systems also varies from serving one viewer to serving a large classroom. Most prior educational stereoscopic applications have only been used for small groups or individual viewers, not for large classroom settings. With advances in hardware and software, most PC computers now have the capability to support stereoscopic viewing. Thus, stereoscopic viewing has now become affordable for large classroom use.

Low-cost Stereoscopic Technology

Low-cost stereoscopic technology uses inexpensive devices such as PC workstations and 3-D glasses, combined with stereoscopic-enabled software applications, to partially immerse viewers in a virtual scene. Currently, most PC workstations have stereoscopic graphic display capability built into their graphics card chip sets. Therefore, with plug-in software for separating right-eye and left-eye and images, PC applications can now display stereoscopic views.

PC-based stereoscopic systems typically use one of several types of special viewing glasses to selectively send the right- and the left-eye images to the correct eyes. Depending upon the type of glasses used, stereo systems can be classified into active or passive stereo systems. "active" systems use glasses with electronic components; "passive" systems use glasses without electronic components. In active stereo systems, stereo images are presented by rapidly alternating the display of right-eye and left-eye images, while alternately masking the right and left eye using synchronous shutter eyewear, such as LCD shutter glasses.

Passive anaglyphic stereo systems are the most common and basic type of stereo systems. They are popular because they are very inexpensive, and cost is often a critical factor in public environments. One pair of red-blue anaglyphic glasses only costs about (U.S.) 80¢. Passive anaglyphic systems create a different colored image for the right and left eye. Users then view the images using anaglyphic paper glasses made from colored filters (e.g., blue for the right eye and red for the left eye).

One advantage for the anaglyphic stereo images is that they can be projected onto a big screen using regular LCD projectors without any special hardware. Thus, anaglyphic stereo systems can be easily implemented by most users for use with large audiences. However, image quality in passive anaglyphic systems is relatively poor, and they can only display gray-colored images. The lack of colored viewing capability is one of the major drawbacks of anaglyphic passive stereo systems.

Another method for passive stereo viewing is based on the principle of light polarization. With oppositely polarized filters attached to two projectors and matching filters in a pair of glasses, right- and left-eye images can be separated, and multiple colors can be preserved. However, polarized stereo systems are relatively expensive because they need special projectors for polarizing the left- and right-eye images. Polarized projectors usually cost about (U.S.) $5-10K.

Stereoscopic technology in education

In prior educational studies, stereoscopic technology has been considered an effective learning and educational tool for helping students understand abstract information and complex models. For example, Haufmann, Schmalstieg, and Wagner (2000) used a stereoscopic environment in mathematics and geometry education, especially in vector analysis and descriptive geometry. Bell and Fogler (1998) used stereo models to help students understand molecular mechanisms.

Many instructors have used anaglyphic technology, since it is very empirical, to enhance instructional delivery, especially in the geosci-

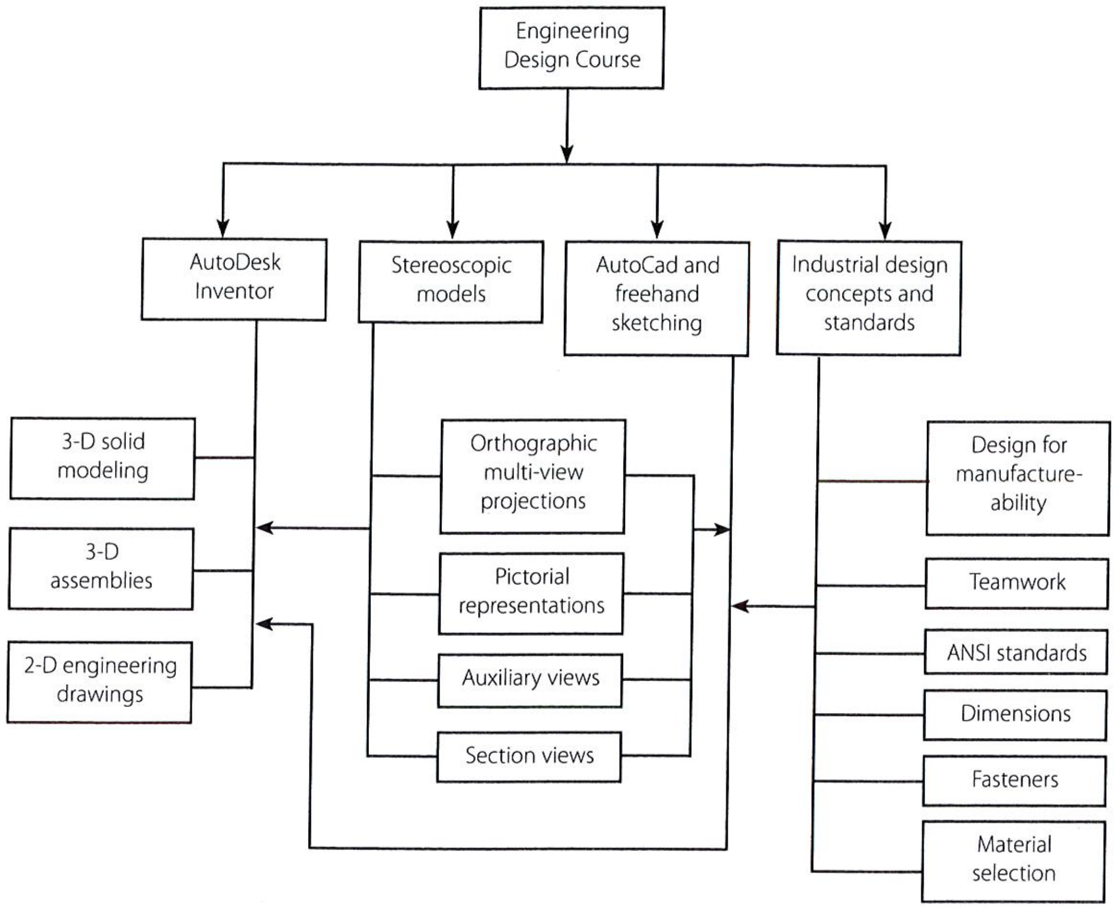

Figure 1. Integrating stereoscopic models into an entry-level design course

ences and biology (Lynn, 1993; Perkins, Hashmi, & Jordan, 1993). In addition, anaglyphic technology is an excellent basic tool for teaching students how stereoscopic images are created. However, although low-cost anaglyphic stereoscopic technology has existed for many years, in prior studies, most images were printed on paper. For example, Pearce (1985) introduced red-green color stereo images, printed on paper, into descriptive geometry instruction. As a result, the viewers could not orient or manipulate the models to look at different views.

Okamura and Lieu (1993) wrote a computer program to generated red-green anaglyphic images, on computer monitor screens, for enhancing descriptive geometry instruction. They concluded that their low-cost stereoscopic viewing system was ideal for educational use. The initial response from students was positive. Students liked the concept of having 3-D stereo models as well as a new, interesting way of learning. However, they did not collect any formal qualitative or quantitative survey results. After the study given by Okamura and Lieu, little literature exists concerning using computer-generated anaglyphic stereoscopic images in design and graphics education. Reasons for the lack of continued research or follow-up studies may have been the technical difficulty involved in developing stereoscopic viewing algorithms and displaying stereo models on computers. However, recently, stereoscopic viewing software and hardware has become more available, due to a growing stereoscopic virtual reality gaming industry. Some free stereoscopic software tools are even available in downloadable form on the Internet. Now, since more low-cost stereoscopic software and hardware tools are available, research concerning the effectiveness and cost-effectiveness of integrating computer-generated stereo images into large classroom, for full-time instructional

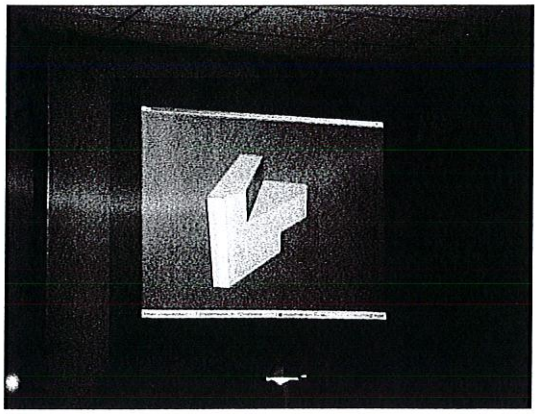

Figure 2 Stereoscopic models projected on a big screen at the front of the classroom

use, and pedagogical issues related to integrating the tools into design and graphics education can be completed.

Methodology

In this study, computer-generated anaglyphic stereo models were integrated into to an introductory design course, during the Spring 2003 semester, to help students visualize 3-D graphic models. Thirty-two students were in the class. Mental Rotation Test (MRT) scores were compared with results from the Fall 2002 semester, in which the same models were used and displayed in the classroom, but without stereoscopic viewing. A student survey concerning using stereo models was also conducted during the Spring 2003 semester.

The shaded blocks in the course map shown in Figure 1 describe how stereo models were integrated into the existing course. Example models from an engineering graphics workbook were created using Autodesk Inventor, before the pilot test lectures, which covered multi-view projections, pictorial views, auxiliary views, and section views. Free software was downloaded from OpenSceneGraph Professional Services (http://openscenegraph.sourceforge.net/) to translate the CAD models into red-blue anaglyphic stereo models. The software tool allows viewers to orientate, zoom, and translate the models. The red-blue stereoscopic tools were used in lectures, with free-hand sketching, to help students understand 3-D concepts and the relationships between different views.

During lectures, the instructor first projected the red-blue stereo models onto a big screen at proper times (Figure 2). The instructor also

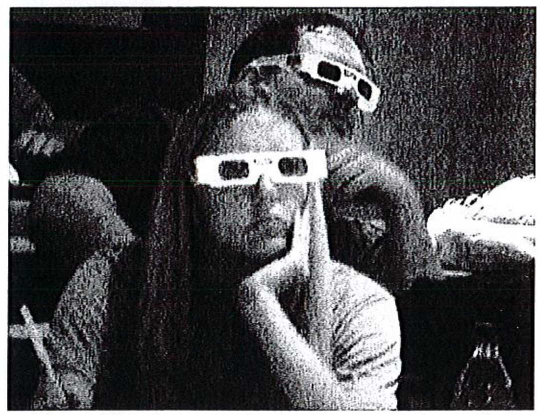

Figure 3 Students experiencing stereoscopic instruction

manipulated the models to different orientations to show the different object views. Students wore the anaglyphic 3-D glasses for viewing the stereoscopic images (Figure 3). After students acquired spatial knowledge of a 3-D model, by stereoscopic viewing, they were asked to free-hand sketch projection views of the object.

The Mental Rotation Test (MRT) (Vandenberg & Kuse, 1978) was administered to evaluate students' visualization abilities. Testing occurred at the beginning and end of two different semesters. MRT scores from the two semesters were compared using two-sample t-tests. A statistical significance level of $p = 0.05$ was used for comparing sets of MRT scores. MRT scores from the beginning and end of each semester were also compared, within groups. During Fall 2002, traditional CAD tools were used during classroom lectures. The instructor projected the same models on the screen, but without stereoscopic viewing capability. During Spring 2003, passive anaglyphic stereoscopic tools were used during classroom lectures. A questionnaire was also administered, at the end of the Spring 2003 semester, to collect

MRT Scores		N	Mean	Standard Deviation	Mean Difference	Standard Deviation
(1) Fall 2002 (without stereo models)	Pre-test	35	18.06	6.30	9.31	4.80
	Post-test	35	27.37	6.93		
(2) Spring 2003 (with stereo models)	Pre-test	27	18.44	7.01	8.70	4.92
	Post-test	27	27.15	6.92		

Table 1 Pre-test and post-test MRT scores

students' comments about using the stereo models. The purpose of the questionnaire was to identify issues and concerns students had about viewing stereo models.

Results

MRT Results

MRT results for the pilot study are shown in Table 1. Results indicate that there was a statistically significant increase in students' visualization skills during both semesters, with a mean difference between pre-test and post-test scores of approximately 9 points on the MRT (p= 0.05). The pilot study results do not indicate a statistically significant difference between using traditional CAD tools and passive stereoscopic tools for classroom lectures. However, several uncontrolled factors still need to be taken into consideration (e.g., image quality, exposure time, and personal interaction with the stereo models).

Survey Results

A survey was developed to both quantitatively and qualitatively measure student perceptions related to their stereoscopic experiences, with a series of statements using a five-point Likert scale. The scale used was:

1. Strongly Disagree
2. Disagree
3. Not sure
4. Agree
5. Strongly Agree

The results of the survey are presented in Table 2. Each student was asked to rate 15 questions concerning usefulness and satisfaction with using the stereo models to enhance their learning. Overall, the results lead to two observations.

First, the students' opinions tended to be somewhat divided, and balanced about the mean on the Likert scale. This can be seen from the result mean values, which were all very close to 3 (not sure). However, overall, students' opinions appear to be slightly positive. For the eight statements that measure positive feelings about the stereoscopic tools, the average student response is 3.23. For the seven statements that measure negative feelings about the anaglyphic stereoscopic tools, the average student response is 2.44. Students gave the strongest average response overall (3.56) to Statement 9, " The three-dimensional models helped me to learn."

Second, although the students' opinions were divided, there were few extreme opinions. This can be seen from the relatively low percentages for responses in the "strongly disagree" and "strongly agree" categories. The results may indicate that the students did not have had enough exposure to stereoscopic technology to develop strong opinions about the effectiveness of stereoscopic tools for learning, or that they did not have a strong basis for comparison (did not have significant prior experience learning design and graphics materials using other methods).

In the second part of the questionnaire, students were asked about the "effectiveness", "strengths", and "weaknesses" of the stereo models in an open-ended question format. Positive comments about the effectiveness of the stereo models included: "stereoscopic models helped me get an overview of what the object really looked like," "We are actually able to see the model and understand the 3-D perspective," "It gave a better view of 3-D models than the 2-D book," "It was interesting, fun, and I could see the 3-D forms better", and "They helped visualize the object". Other than the positive comments, some students gave some negative comments about the effectiveness of the stereo models which include: "Not very - helped see the solid view", and "the glasses didn't help at all."

Question	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	All Students Mean N=32
1. I found the stereo models motivated me to learn.	6.3	21.9	37.5	34.4	0 %	3.00
2. The stereo models used in class were boring and uninteresting.	9.4	34.4	21.9	25.0	9.4	2.91
3. The stereo models were enjoyable and educational.	3.1	21.9	28.1	40.6	6.3	3.25
4. The stereo models were not easy to understand.	12.5	34.4	31.3	18.8	3.1	2.66
5. I could learn faster using stereo models than using the engineering graphics workbook.	3.1	12.5	43.8	28.1	12.5	3.34
6. I cannot see the stereoscopic view of the stereo models.	6.3	28.1	40.6	15.6	9.4	2.94
7. I could not clearly understand the material presented in the stereo models.	3.1	50.0	18.8	18.8	9.4	2.81
8. I believe that the stereo models would be excellent educational tool.	3.1	31.3	15.6	46.9	3.1	3.16
9. The three-dimensional models helped me to learn.	3.1	12.5	21.9	50.0	12.5	3.56
10. I believe that I could learn more in an introductory graphics course if stereo models such as these were available.	0 %	28.1	40.6	28.1	3.1	3.06
11. The simulated graphics of the stereo models enhanced educational value.	0 %	21.9	37.5	34.4	6.3	3.25
12. Viewing a stereo model makes me feel dizzy.	21.9	28.1	12.5	18.8	18.8	2.84
13. The stereo models were not an effective way to learn about engineering drawing.	18.8	21.9	25.0	31.3	3.1	2.78
14. I would appreciate the interaction with the stereo models.	0 %	15.6	43.8	40.6	0 %	3.25
15. The stereo models did not help me learn engineering graphics.	9.4	34.4	28.1	21.9	6.3	2.81

Table 2 Usefulness and satisfaction with the stereo models

Comments about the "strengths" of the stereo models include: "Help visualize the object better", "Fun, Motivate", "Not as boring", "Great view", "Better interpretation, fun", "Better 3-D view", "Works well", "Good visualization tool", "Gives you another perspective view", and "Easier to understand our models".

Some participants put valuable comments in the "weaknesses" section. Their responses were related to specific aspects of the technology or to particular individual differences. The comments included: "Couldn't see it well," "Dizzying, goofy glasses," "Can't physically touch it, still computer oriented," "I can see it well through 2-D," "Contrast was not clear enough on surfaces", and "eye hurt."

Conclusions and Discussions

This pilot-test investigates the effectiveness of integrating computer-generated low-cost anaglyphic stereoscopic models into an entry-level design course, in a large classroom setting. Geometric models were created, using a CAD tool, and then translated into red-blue anaglyphic stereo models, using a free software tool provided by OpenSceneGraph Professional Services. The computer-generated stereo models were displayed and manipulated into different orientations, at the front of a classroom, at proper times during lectures or sketching exercises to help students understand the relationships between the 2-D representations and 3-D models.

The study also introduces formal qualitative and quantitative instruments for measuring the impacts of using stereoscopic technology in education: MRT tests and student surveys. Prior related studies did not use quantitative measures to support conclusions about the impacts of stereoscopic technology in education.

In the pilot study conducted, MRT test results indicate that student visualization skills improved by similar amounts, using either a low-cost anaglyphic 3D stereo system or a traditional 2D CAD system for classroom lectures. However, qualitative and quantitative survey results indicate that most students enjoy learning design and graphics instructional materials with the aid of stereo models and that stereo models help most students to visualize 3-D objects better. In particular, most students felt that the stereo models were interesting and fun, and that they made class less mundane. The instructor also observed that students were more engaged in lectures when the stereoscopic tools were used.

The effectiveness and quality of stereo models are both greatly affected by the stereoscopic system used. In the given study, some students felt that the inexpensive anaglyphic stereoscopic system used did not always work well. Since the anaglyphic stereoscopic system used inexpensive red-blue paper glasses, models were in gray color only. Thus, the contrast was not clear on model surfaces. As a result, some students' eyes hurt, they became dizzy, or sometimes it was hard for them to see the 3-D effect.

The effectiveness of stereo models is also affected by each individual's physical reactions. In the pilot test conducted, some students felt that using stereo models was not necessary because they could visualize 3-D models quite well using 2-D graphics. Some students could not see the stereoscopic effect in the projected 3-D images, or they felt uncomfortable and dizzy using the stereoscopic glasses.

Students also stated that they would like to have opportunities to actively interact with stereo models, rather than being passive viewers in the classroom. Inviting students to manipulate the models during the lectures could further increase students' engagement in class. Providing students more opportunities to experience the new technologies through direct interaction may further improve effectiveness.

Student survey results support conclusions drawn in prior studies related to using stereoscopic tools in education, which indicated, based upon student and instructor comments, that stereoscopic technology is a useful and engaging tool for education. The investigator believes that pilot study findings and comments are positive enough to continue to explore possibilities for implementation.

Future Work

This study provides a roadmap for further implementing and refining stereoscopic technology for use in design and graphics education. Further research is needed concerning the connection between using stereoscopic visualization tools and improving concept learning and visualization skills. Different or better methods may be needed for measuring, quantitatively, the positive impact reported by students and investigators in both prior studies and the pilot study. Although the MRT results for the test semesters are similar, students' comments related to using the stereoscopic visualization tools indicated enhanced learning effects. Test instruments, other than the MRT, could be developed to better measure the apparent learning effects. Instruments that incorporate the stereoscopic viewing technology might be particularly useful.

Additional research is also needed for determining the most cost-effective stereoscopic technology for improving design and graphics education, in a large classroom setting. Other stereoscopic technologies, such as passive polarized stereo systems, CAVE, and head-mounted displays, need to be tested and compared to anaglyphic systems. Some stereoscopic systems are relatively expensive, although their image quality and degree of immersion are much better than anaglyphic systems.

Several pedagogical issues concerning how to best use stereoscopic tools to promote learning also need to be studied. For example, students might be more interested in viewing models they create. Research is also needed concerning how more hands-on opportunities, such as using stereoscopic tools for student team-design projects and presentations, impacts visualization skill development and learning. In addition, the pilot study only used relatively simple individual models. Stereoscopic technologies might be most useful for visualizing complex mechanisms and motions.

Adding haptic devices to provide force feedback could help increase the realism of the stereo models. Other factors, for example exposure time and physical comfort, that might influence learning in stereoscopic environments, also need to be considered.

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Creating Animated Diagrams with Flash

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Abstract

Photographs, illustrations and diagrams have long been used as a way to support and enhance textual material. The emergence of the Web as a teaching platform has focused the attention of educators on the use of multimedia as an instructional medium. Sound, video and animation are the primary components of multimedia. Animation can be a powerful tool for introducing concepts and processes. An animated diagram can support the text or go beyond the written explanation. Adding motion to a process diagram or an illustration, which shows how something works, can help to explain difficult concepts. Although most educators avoid multimedia packages due to their expense and complexity, Flash is a great tool for the beginner. Flash offers a quick way to create simple animations to be used on the Web.

Introduction

Merging text and graphics has always proven to be effective in fostering learning. Multimedia instruction strives to further enhance the learning process by adding other media elements. Multimedia is defined as applications that bring together multiple types of media such as text, illustrations, photos, sounds, animations and video with some measure of interactivity (Apple, 1994). One of the main characteristics of multimedia is that it is interactive; it makes the viewer an active part of the presentation instead of a passive observer (Apple, 1994). Since multimedia employs a variety of media, it stimulates multiple senses. The value of multimedia learning materials is that they can accommodate many learning styles. Horton states "The more channels used to process the information, the more areas of the brain are activated and the more locations the information is stored in" (1991). Dale's Cone of Learning points out that the more involvement the learner has with the subject matter, the higher the retention rate (Dale, 1969).

As educators, we strive to present course materials in a variety of ways to emphasize and re-emphasize concepts. Most educators realize that different students respond to certain teaching techniques more than others. Some students only need to hear and/or read an explanation, whereas others need hands-on experimentation. For those in the latter group, a static illustration might not be enough, whereas an animated sequence that the student can stop and start might solidify the process. Animated sequences are engaging to the viewer and can be used to represent information that is difficult to explain with static images (Brinck et al., 2002).

Animated Diagrams

Animation is a subset of instructional visuals (Rieber, 1990). Just as static illustrations support textual and verbal explanations, animation adds another element of focus. Gonzales (1996) defined animation as "a series of varying images presented dynamically according to user action in ways that help the user to perceive a continuous change over time and develop a more appropriate

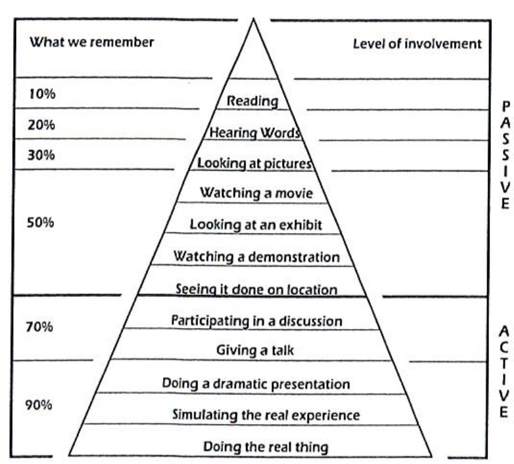

Figure 1 Dale's Cone of Learning

mental model of the task." While diagrams are used to show how various components work as a whole (Horton, 1991), animated diagrams are useful for showing sequences. An ordered sequence of images answers the questions when? why? and how? (Meyer, 1997). For example, consider an animation that shows how a car's brake system works. The viewer could learn that the brake shoes are activated as the driver pushes down on the brake pedal (when) and the fluid pressure increases (why) and activates a set of pistons (how) (Mayer, 2001). Animated sequences are best used to explain a process or casual relationships or illustrate a chronological order of events (Meyer, 1997). There are a variety of reasons to use animated sequences: 1) To enrich graphical representation, 2) To illustrate change over time 3) To illustrate how a mechanical device works and 4) to show a process or procedure (Horton, 1991; Nielsen, 1999).

Enriching Representation

Typically, graphics are used to illustrate things that are difficult to describe with words alone. A simple illustration of how to install a video card clarifies the location of and relationship between the parts more than words alone.

In the same way, using motion to depict changes over time or the interactions of moving parts should enhance the visualization of the sequence. Instead of examining a series of static images to convey how a pump works, the viewer can start and stop an animation or run it in slow motion to see how the pump functions.

Showing Change Over Time

Often, the process being illustrated happens over a period of time. For example, the way an oil field is formed over a period of many years or the second by second changes in a bullet from firing through impact are both time-based events. These types of processes can be better communicated through animation. The changes can be shown subtly with transitions, that gradually fade from one stage to the next, or precisely with step-by-step or on-going sequences that the viewer can control.

Illustrating a Mechanical Device

The most common use for animated diagrams is showing how something works. Whether it's a pump, an engine or an electrical device, an animated diagram can illustrate how the parts interact and in what sequence. As with most graphic devices, diagrams offer a simplified version of the device to focus on the process being illustrated. Vector line images, such as those from Flash, using minimal color and shading, are well suited to this task because of their clarity and precision.

Showing a Process or Procedure

Animated diagrams are also appropriate for demonstrating processes or procedures. For example, an animated diagram can show how a virus invades a cell or how a casting is made. These time-dependent actions are difficult for observers to explore repeatedly in real life and in real time. With an animated diagram, however, the steps of these processes can be repeated indefinitely and dissected by curious minds until they reveal themselves more fully—allowing for a better understanding of the process. The power of visual thinking is combined with that of repetition in the use of animated diagrams.

Flash Animations

Flash is an animation tool that can be used to create effective animations that are efficient for use on the Web. It uses vector imaging that delivers resolution independent graphics with minimal file sizes. This makes them ideal for Internet transfer or insertion into multimedia presentation packages.

Flash also innovated the technique of anti-aliasing vector graphics for a more attractive look. Anti-aliasing softens the traditional sharp edges associated with vector imaging by using blending algorithms typically used in raster environments. This gives Flash graphics a more appealing look while retaining the precision and reproducibility of vector animation, making Flash a good choice for animated diagrams.

Flash animations are frame-based and often utilize scripting. This assures consistency of temporal elements and allows the developer to create levels of interactivity that range from limited to complex (Kaye, 2003).

Research On Animation

Research related to animated diagrams has shown varied results. Bétrancourt and Tversky, in their review of animation studies, found that the primary problem was the methodology of the studies (Bétrancourt & Tversky, 2000). Some of the studies compared static and animated graphics, some compared text passages with animated displays, some compared computer- assisted-learning to classroom learning and others focused on how viewing the animation affected learning performance.

Further, when comparing static graphics to animated graphics, it was found that often the animated sequences included finer steps or provided information not available in the static image. The authors conclude, "... most of the successes of animation seem to be due to the extra information they convey, rather than the animation of that information." (Bétrancourt & Tversky, 2000) In other words, studies have not shown positive results that can support the effectiveness of animation per se. The research has shown, however, some of the problems associated with using educational animations, as well as, things to consider when designing animations.

Considerations When Using Animated Diagrams

Goals

As with any use of graphics, the effectiveness of an animation is determined by the goals, the implementation and viewer interaction (Bétrancourt & Tversky, 2000). Typically, graphics are included to help readers by 1) making the textual information more aesthetically pleasing (decoration); 2) making information easier to visualize (representation); 3) making information easier to remember (transformation); 4) organizing the information (organization); and 5) increasing understanding (interpretation) (Levin, Anglin & Carney, 1987). Since animated diagrams are a subset of graphics they can serve all of the same goals.

What is the goal of the animation? Is it to engage the viewer by offering an alternative learning method? Is the goal to aid comprehension? Studies have shown that computer animation "holds motivation" (Reiber, 1991); that suggests that computer animation can serve as an effective teaching tool.

Implementation

Jones & Scaife (2000) point out several features of animation, that can affect perception and readability. They are design dimensions, representation and temporal aspects.

First, consider the design dimensions, which refer to the amount and complexity of the information being illustrated. Things to consider include the complexity of the image, the amount of information presented at one time and the clarity of the process being illustrated. For example, schematic representations were found to be more conducive to learning than pictorials (Hegarty

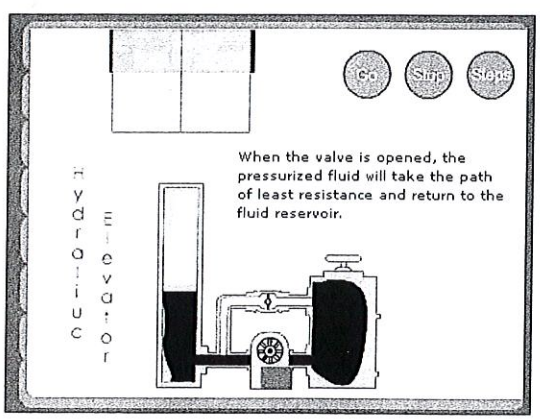

Figure 2 Elevator 1

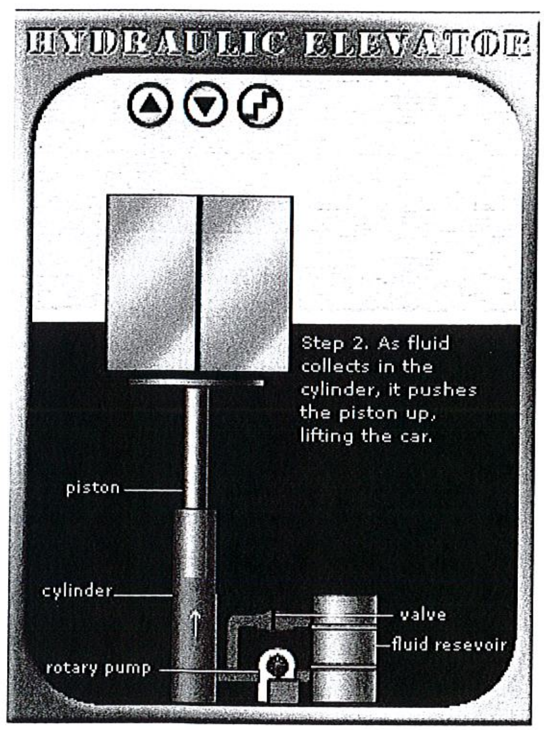

Figure 3 Elevator 2

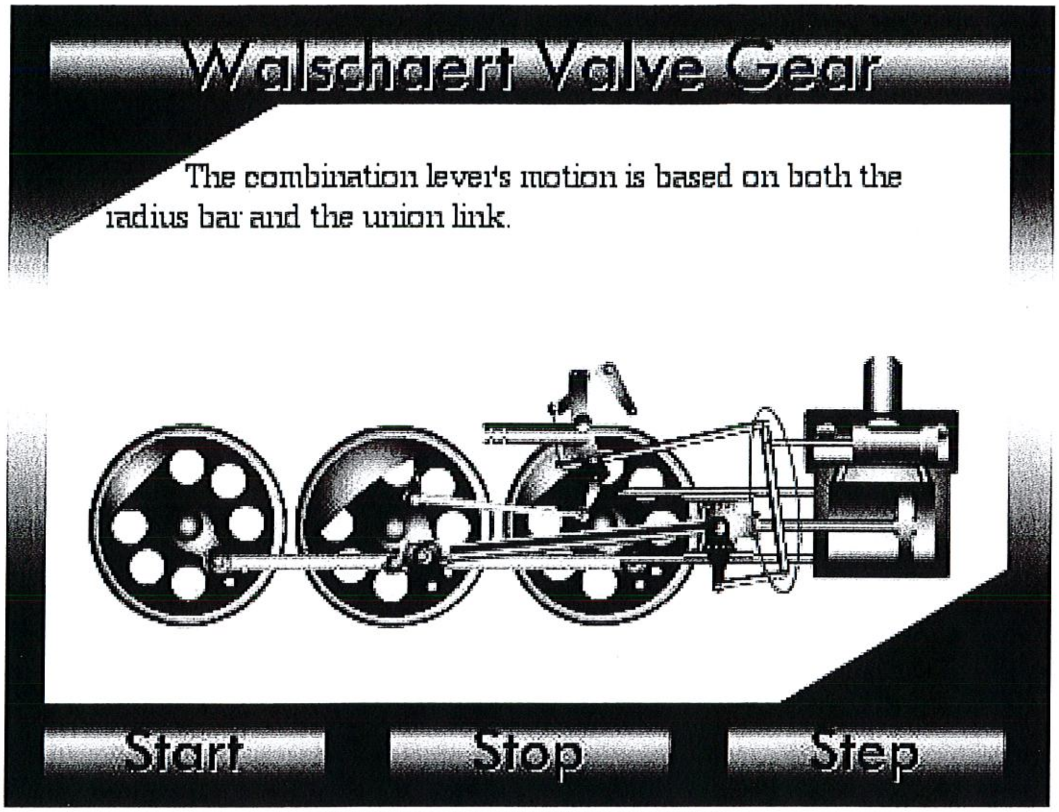

Figure 4 Gear animation with highlighted area

& Kozhevnikov, 1999). We can conclude that straightforward images, that eliminate excessive detail, help the viewer to focus on the process. Also, the complexity of the animation should be suitable for the user. The more inexperienced user requires simpler and better-documented animations whereas a more experienced user can comprehend something more abstract and complex (Scaife & Rogers, 1996).

Second, consider the representation of the process being animated or how the motion is depicted. For example, the order and number of steps and the amount of detail can vary. In the examples shown in figures 2 and 3, although both show the operation of a hydraulic elevator, they vary in several ways. The first example (Figure 2) uses color shapes to indicate the hydraulic fluid; the second example simply uses an arrow to show the direction of flow. When viewing the animations side by side, the first one is more effective because it conveys both direction and fluidity. The second example (Figure 3) labels the parts; the first one rotates the pump when the liquid moves. Both illustrate the same process in slightly different ways, each having features that, if combined, would offer the best sequence.

Third, consider temporal aspects such as speed, direction and the relationship between parts over time. Although a process might be clearer when shown over time, if the sequence happens too quickly it might be difficult to understand. If too many parts are moving at the same time, pop-up labels with an explanation might help. Highlights can also be used to help the viewer focus on a particular part at a particular time. In the example shown in Figure 4, the pertinent step is circled on the diagram to direct the reader's attention to the correct location on the diagram.

Jones & Scaife (2000) state "Focusing and sequencing relieves learners from deciding which aspects are important and in what order to 'read' information, which may reduce confusion and enable focus of attention on relevant aspects."

Countering The Drawbacks Of Animation

There are several drawbacks associated with animated diagrams. First, animations are fleeting (Morrison et al., 2000). Typically, the user has little control over the animation and must retain

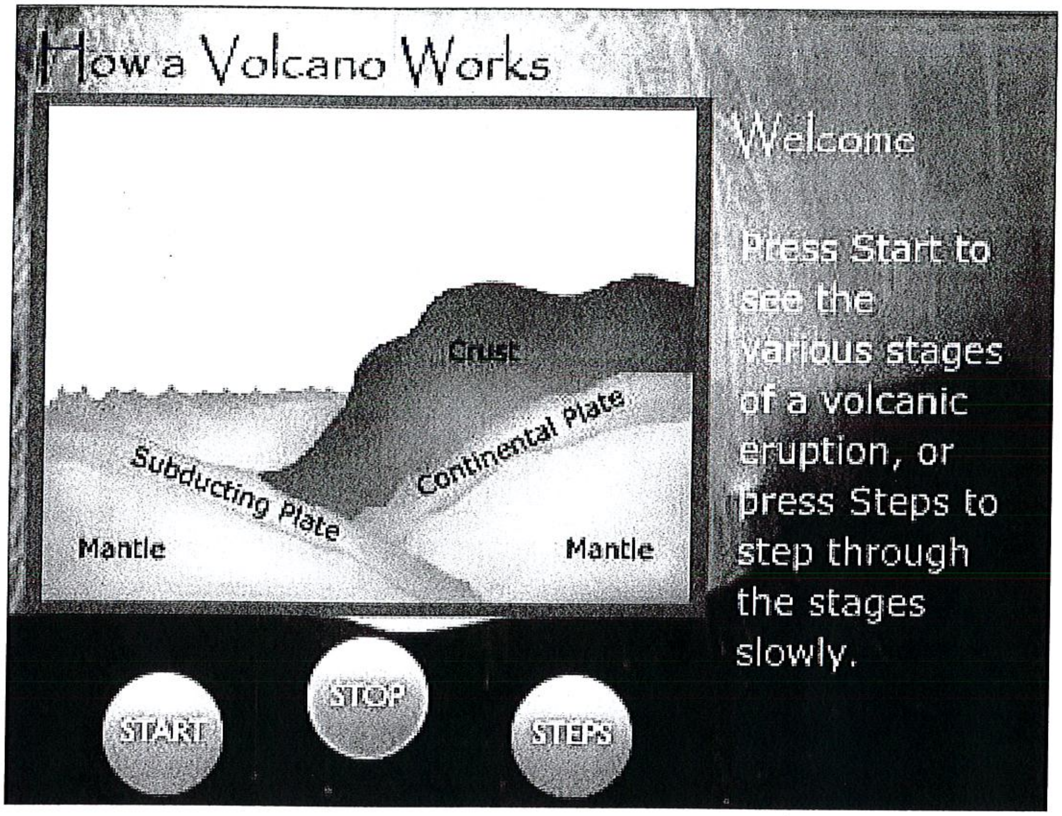

Figure 5 Volcano animation with controls

and integrate information over the course of the animation. To overcome this problem, give the user some control by adding a slow option or a static step-by-step playback with some instructions as show in Figures 5 and 6. This allows the user to replay both the motion and the explanation at will.

Second, animations can result in cognitive/memory overload if too much information is presented at the same time or in a complex illustration (Kaiser et al, 1992). Jones & Scaife (2000) state that parsing motion sequences can lead to better understanding of the dynamics of the sequence. When the animation shows the interaction of multiple parts at a representational speed, the complexity might overwhelm the viewer. To compensate, the process can be broken into multiple stages that focus on different aspects of the overall process as shown in Figure 6. Likewise, allowing the user some level of interactivity gives them more control of the animation.

Third, as with any form of graphical communication, the information or message must be clear. Since the words and images are minimized, they must be appropriately focused on the learning task. Mayer (2001) states that for multimedia learning to be successful, the learner must coordinate five cognitive processes. As information is presented, the multimedia user will actively monitor and process the presented information, using the five cognitive processes: 1) selecting relevant words, 2) selecting relevant images, 3) organizing words into a "verbal model," 4) organizing images into a "pictorial model," 5) integrating the two models.

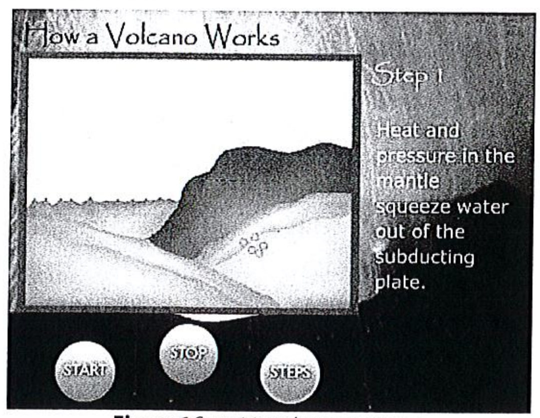

Figure 6 Step 1 in volcano sequence

When designing an animation, consideration needs to be given to things that will aid the learner in processing the information. Words can be presented as text and speech to encourage dual-channel learning and images can be simplified to remove extraneous elements and highlight important areas. Since images, text and spoken words are processed differently, the process of absorbing and sorting the data is complex and care must be taken to facilitate this process in a multimedia environment.

Mayer provides another set of guidelines that lead to successful multimedia, which can be incorporated into the design of animated learning sequences. He has identified five conditions that facilitate learning in a multimedia environment: 1) spatial contiguity, 2) temporal contiguity, 3) coherence, 4) modality, and 5) redundancy (Mayer, 2001).

To achieve spatial contiguity, place related text and images near to each other in the layout. For temporal contiguity, present the words and images at the same time rather than in a sequence. Coherence can be achieved by minimizing extraneous sounds, words and images, which may distract from the relevant material. The principle of modality states that a multimedia user learns better if words are spoken rather than written. Finally, learners do better when words are spoken rather than both spoken and written.

Levels Of Interaction

As Dale's cone of learning shows, learners tend to absorb more as their interaction increases (Dale, 1969). The complexity of an animation can vary based on the subject, the user, the goal and the skill of the developer. Many educators are capable of creating simple animations with Flash. Although more advance sequences might require expert assistance, the educator can still control the design and the effectiveness by following some of the guidelines presented earlier in this paper. Following are descriptions of the different levels of interactivity that can be achieved.

Start/Stop Control

At its basic level, interactivity entails controlling the timeline of an animated diagram. This means the user is able to start and stop an animation as desired. Often times this can also mean the animation plays through without halting, but the user can play it over and over to better understand the process being shown. At this level of interaction, audio components and special effects are usually left out

For the programmer, this level of interactivity is the simplest to devise. There is a major reduction in scripting. There may also be a reduction in communication. Start/stop control is most useful for short and simple repetitive animations-such as the turning of an electric motor-otherwise the nuances of more complex tasks may be glossed over in the animation and lost on the user.

Step-by-Step

At this level of interactivity the user would view the animation in a progression of steps. The viewer could pause in between each step for comprehension or repeat the material in the previous step. If part of the process is confusing, the user could focus on a specific step-repeating it until they were ready to proceed further.

At this level, the introduction of written and/ or audio components can be added to the animation. Animated lessons alone are powerful tools, but additional dimensions of audio or written explanations increase the level of communication.

Most PCs today have some sort of simple audio recording software. If not, there is a variety of shareware and freeware available to aid in the recording of low to mid-grade audio files. These can easily be added to a Flash timeline and set to play along with defined steps in the process. The main drawback to the addition of audio files to an animation is that it increases the file size. Often times two or three minutes of sound can greatly increase the file size of a Flash document. Since Flash files are typically small, it may not be a problem. However, if web delivery is a primary concern, written instructions may be preferred to keep download times short.

Whether written or verbal, supplemental instructions in a step-by-step animation can make a big difference in broadening the communicative value of a piece and can make it more effective.

User Input

Some processes are best understood through the manipulation of variables. For example, Pascal's law of pressurized fluids may be better interpreted visually if an interactive Flash animation is used, which allows the user to input data and see how it affects the process.

This type of animation will certainly involve some scripting in order to retrieve an inputted variable and modify the animation, but the benefits are great. By allowing the user to manipulate a process in such a way, the user can observe the changes, as data is input. The user can observe how different variables change the process and its importance to the overall sequence. In addition to written or audio instructions, questions about cause and effect can be a part of the animated lesson to encourage experimentation.

Full Interactivity

The highest level of interactivity is one in which the user can input at least one moderating variable in the process and also manipulate the graphics using a mouse or keyboard. This ability to handle and control elements of an animation depends upon the scripting abilities of the developer.

With the additional dimension of object manipulation, a user is often more likely to become interested and engaged with a process animation. It is the closest thing to being able to touch the objects in the animation, adding another level of control. This interactivity may not be necessary for basic processes, or even particularly complex ones. The need for user control is case dependant and to be determined by the developer.

It is important to remember control over interactivity is in the hands of the developer and designer of a Flash process animation. There is a limitless combination of interactive elements possible. It is always important to consider the process being shown when determining which of these levels is appropriate and beneficial when weighed against the development time.

Summary

In summary, animated diagrams can serve as an effective teaching tool. Animations can be used in a teaching situation as support to lecture material or as additional study materials for out-of-class assignments.

They can also serve as a problem-solving device, that students can use to independently draw conclusions by changing variables and seeing the effects. Although they are sometimes time-consuming to create they offer another tool to facilitate learning in a way that holds a student's interest.

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A Methodology for Optimum Selection of Solid Modeling Software

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Abstract

This study proposes a methodology that would enable a design educator or a design practitioner to optimally select a solid modeling software (solid modeler) for varying objectives. Specifically, tasks accomplished to propose the methodology include: 1) reviewing past literature to compile the criteria used for selecting solid modelers, 2) preliminary comparison of a number of solid modelers on established criteria, 3) running designed experiments for comparing the user performance on predetermined solid modeling functions, and 4) compiling the experience gained as a generic methodology. The application was completed over a two-year period while a systematic selection process was undertaken at The Pennsylvania State University (Penn State). This paper documents the entire selection process including the student design performance data collected. The set of outcomes of the study is expected to aid companies and design educators in making solid modeler selection decisions.

Introduction

One of the necessities for a company to succeed in today's global competition is its ability to identify customer needs and to quickly create products that meet these needs. This necessity, which involves a set of activities beginning with the recognition of an opportunity and ending in the delivery of a product to the customer, is the rapid product development process. Rapid product development has been especially important since the late 1980s. There have been vast improvements in the area, mostly focused on searching for ways to shorten the development process duration. Among these, the advancement in design software is very significant. Accordingly, when preparing engineering students for similar responsibilities, integrating a solid modeler to design teaching is a must. However, it is not a trivial task. Associated with the integration, several questions need to be answered. For example, 1) Does the software have educational materials? 2) Are the educational materials adequate? 3) Is it easy and quick for students to learn? 4) Can the faculty gain the necessary knowledge and expertise to teach it in a short time? and 5) Does learning the software help students learn another solid modeling software easier? Beyond integrating a solid modeling software to design teaching, when one considers how a company might consider selecting a design software, more questions would arise such as: 1) Does the design software satisfy the needs of the product development process? 2) How efficient is it? and 3) How does it compare to similar products? These questions are important to answer when the goal is to shorten the product development process by utilizing cutting edge design software solutions.

In order to provide a decision tool for design educators and practitioners, this study proposes a methodology for optimally selecting a solid modeler for varying objectives. Furthermore, application results of the methodology are presented. The application was completed over a two-year period while a systematic selection process was undertaken at Penn State. This paper documents the entire selection process including literature review, the proposed solid modeler comparison methodology and its application results.

Literature Review

In order to 1) compile the criteria for use during solid modeler selection process, and 2) to review previous solid modeler comparison studies, a comprehensive literature search was completed. Below is a summary of the findings of the literature search.

Solid modeling was developed in the mid 1970s as a response to the need for informational completeness in geometric modeling, and can be defined as a consistent set of principles for computer modeling of three-dimensional solids (Shapiro, 2002). It uses the mathematical abstraction of real artifacts, which are transferred into computer representations (Requicha, 1980; Requicha and Voelcker, 1981). Solid modeling was intended to be a universal technology for developing engineering languages that must maintain integrity for 1) validity of the object, 2) unambiguous representation, and 3) supporting any and all geometric queries that may be asked of the corresponding physical object (Shapiro, 2002).

Early efforts in solid modeling focused on replacing manual drawings with the unambiguous computer models to automate a variety of engineering tasks (e.g., design and visualization of parts and assemblies, computation of mass, volume, surface area of parts, simulations of mechanisms, and numerically controlled machining processes (Requicha and Voelcker, 1982 and 1983; Voelcker and Requicha, 1993). Today, it is seen as an integral tool for product development because "... (it) allows everyone involved in the development of a new product—marketing/sales staff, shop-floor personnel, logistics and support staff, and customers—to add their input when changes can be made quickly and easily" (Schmitz, 2000).

Product design related applications of solid modeling are classified as 1) geometric design, 2) analysis and simulation, 3) dynamic analysis, and 4) planning and generation (Shapiro, 2002). Furthermore, while at one time the statement "... there are currently no CAD systems that live up to the requirements of the concept design" (Van Dijk Casper, 1995) was true, recent experimentation with solid modeling showed improvements in its usage for concept design (Tovey and Owen, 2000). It is also now commonly expected that solid modeling tools include collaborative tools allowing multi-location partners to work on the same design. Nam and Wright's (2001) recent paper includes a good review on design collaboration using solid modelers.

Overall, solid modeling impacts a great variety of concurrent engineering activities, and its importance is increasing due to its wide acceptance. The concurrent engineering activities that use solid modeling include design sketches, space allocation negotiations, detailed design, interactive visualization of assemblies, maintenance-process simulation studies, engineering changes, reusability of design components, analysis of tolerances (Requicha, 1993), 3D-mark-up and product data management, remote collaboration with internet catalogs of parts, electronic interaction with suppliers, analysis (e.g., mechanism analysis or finite elements), process planning and cutter-path generation for machining, assembly and inspection planning, product documentation and marketing (Rossignac and Requicha, 1999).

In a recent article, David Ullman (2001) discusses the current stage of computer aided design (CAD) systems as a design support system and indicates opportunities for software developers to bridge the gap between how designer activities can be supported better in the concurrent engineering realm. Some of these are: 1) an ability to visualize function before geometry is fully defined, 2) extending CAD systems to provide the designer with information about anticipated material and manufacturing methods, 3) generation of a running update of costs as parts and assemblies are changed in real time, and 4) integration of requirements and constraints into the development of parts and assemblies (Ullman, 2001). Despite these current inadequacies of solid modelers, a recent review of design software users survey (CAD Manager 2003 survey) showed that only 30.4% of the design practitioners are using 2D CAD systems. The rest are either using only 3D CAD (6.8%), implementing a hybrid usage of 2D/3D CAD systems (36.4%), or mainly using 2D CAD but evaluating 3D CAD (26.4%) (Green, 2003). This shows the trend in industry in adopting solid modeling software. Furthermore, due to its wide acceptance in industry, its integration to curriculum is changing the engineering/product design teaching (Barr et al., 2002).

Despite the apparent trend in adopting solid modelers in industrial and in educational institutions, selecting the solid modeler that is best suited to the task at hand is not an easy decision. One needs to consider several issues when making such a decision. In addition, one set of criteria that is suitable for one setting may not be for another. For example, criteria used to select a solid modeling software for a design company will differ when compared to the criteria used at an educational setting.

Previous work on solid modeling software comparison include 1) one CAD expert offering his review comments for various products without providing an established set of criteria, 2) rating a software using a predetermined set of criteria, and 3) comparing several similar software packages using predetermined criteria. For example, one can find solid modeler review and ratings in *Professional Engineer* and *CADENCE* (now *CADALYST*) magazines. To give examples: January 1993 issue of the *Professional Engineer* magazine includes a review on four different low cost CAD offerings by a CAD expert, where no particular review criterion is provided (Claypole, 1993). October 2003 issue of *CADENCE* contains a review of CATIA V5 R11. After its review, ratings are provided for the criteria including 1) installation and setup, 2) interface/ease of use, 3) features/functionality, 4) expandability/customization, 5) interoperability/web awareness, 6) support/help, 7) speed, 8) operating systems, and 9) innovation (Greco, 2003). In this sort of rating, there are several problems. For example, it is not possible to compare ratings of two different software completed by different experts. Because the way the experts have interpreted the criteria might be different. Even when the same person evaluates a number of different software, the potential bias the evaluator may have toward one application is very hard to eliminate. In fact, this problem was brought up by Martin and Martin (1994), and studied using published reviews and expertise of reviewers.

It is possible to eliminate the potential bias one can have towards one software by introducing expert users to the comparison. For example, Martin and Martin (1994), and Kurland (1996) invited various vendors to supply operators to partake in separate comparison studies. This way potential biases due to partiality towards one software over the other, or differences between software operators in terms of their skill levels were eliminated. However, in this case it is not clear if the solid modeler can be used by any user as effectively as the expert user partaking in the studies, after an adequate learning period. In other words, experimenting with an expert user cannot yield broader conclusions, because the graphical user interface (GUI) of the modeler can be interpreted differently by different users. Therefore, the GUI determines the overall usability of the modeler and the productivity of the user (Rossignac and Requicha, 1999).

In the 1980s, the introduction of icons and small pictures, which incorporated the desktop mouse as an input mechanism (Rheingold, 1991), changed the human-computer interaction (HCI). The implementation of this GUI takes advantage of the human capability to recognize and process graphical images quickly, and has become a universal HCI standard. Accordingly, most solid modelers use it today. However, the growth of interfaces is a concern for software developers because it might be a barrier in solid modeling education and in engineering practice (Jakimowics and Szewczyk, 2001). It is believed that the layout of GUI elements influences the way the user can interpret them (Ambler, 2000). While the user's correct mental model of the interface can help with his productivity, a false image of the interface might mislead them and limit their ability to work with the software effectively (Genther and Nielsen, 1996). For example, a recent experimental study showed that, if an unknown icon A in software 1 looked like a well-known icon B in software 2, the users supposed that the icon A represented the same function as the icon B, even if both pieces of software were quite different (Szewczyk, 2003). Therefore, it is clear that differences in user mental models of GUI is expected, and thus productivity differences may arise. This point makes it clear that any comparative study of solid modelers should involve multiple users being tested under similar circumstances. The methodology proposed in this paper overcomes the limitations in early comparison studies.

Proposed Methodology

The proposed methodology for solid modeler comparison, which is named as Solid Modeler Evaluation and Comparison Cycle, is given below in steps. Each step is then explained for its rationale for being a part of the methodology.

Solid Modeler Evaluation and Comparison Cycle (SMECC):

Step 1) *Develop a short list of solid modelers for comparison.*

This step is included to compile information to answer the question, "Which solid modelers are used by competitors, suppliers, and customers?" This information is important because in many cases design files need to be exchanged between suppliers and customers, and it is always important to know what the competitors are using. Attention should be given to the multiple solid modeler usage at various levels such as mid-level solid modelers versus high-level modelers. In general, price range of the solid modeler is a good indicator of its level. Therefore, various solid modelers should be clustered based on price ranges and compared within clusters.

Step 2) *Determine the solid modeling functions to be compared.*

Determining the solid modeling functions and criteria for comparison should be context specific because what is needed from the solid modeler depends on the specific applications of the unit that is looking into acquiring the modeler. Table 1 summarizes solid modeler comparison criteria and functions used for empirical testing or proposed for future testing by several practitioners and researchers. In the table, criteria empirically tested, and proposed are indicated by (T) and (P) respectively. Furthermore, for each of the criteria or function listed, a check mark is included to indicate in which previous studies it was proposed or tested. In addition, the number of solid modelers compared is shown in parentheses for each study indicated.

As seen in Table 1, due to the increasing importance of design collaboration because of globalization, outsourcing, and customization, a new set of proposed criteria is focused on collaboration effectiveness of solid modelers. However, published empirical comparison results were not found during the literature survey completed for this research. Therefore, a zero is placed in parenthesis to indicate that while the criteria have been proposed they were not used to compare solid modelers.

A subset of the criteria and functions (from Table 1) should be selected when comparing solid modelers.

Step 3) *Compile a training manual and a schedule for solid modeling learning for the functions determined in step 2.*

This compilation should be done using solid modeler's original training and support manuals, because it is assumed that the developers of the software are in the best position to provide training material. Training manual should cover the selected solid modeling functions and criteria for comparison in Step 2.

Step 4) *Conduct user performance experimentation.*

This step requires a number of users completing the training manual over a predetermined amount of time, and then assessing their performance. User performance should be measured for predetermined solid modeling functions (e.g., extrusion, sweep, revolve, assembly) and using various test problems. It should involve as many users as required to yield a reliable hypothesis testing. Variation in the collected data will be due to various aspects of human performance such as spatial and cognitive abilities, different interpretations of GUI elements by different users.

Step 5) *Analyze the user performance data statistically and conclude.*

Collected data should then be analyzed statistically to conclude with sufficient confidence.

Step 6) *Repeat steps 1-5 in regular intervals.*

The SMECC cycle should be repeated in predetermined intervals for continuously taking advantage of rapid developments in solid modelers.

SMECC Application at Penn State

As Rossignac (2003) acknowledged, there exists a gap between traditional research in any specific field, which is not concerned with educational objectives, and research in education, which is focused on fundamental teaching and learning principles. Accordingly he proposed Education-Driven Research (EDR) for simplifying the formulation of the underlying theoretical foundation and of specific tools and solutions to make them easy to understand and internalize. A similar point of view was taken at Penn State while developing a methodology to select a solid modeler that will enable effective learning without limiting the time to teach design knowledge. With this in mind, a comprehensive solid modeler comparison was initiated during Spring 2002, which was completed in two years. This section summarizes the steps of this two-year effort.

Step 1) *Develop a short list of solid modelers for comparison.*

For this purpose, using the list of top 30 engineering schools in year 2002 (provided by

Comparison Criteria or Functions Tested or Proposed (T or P)	Mackrell 1992, (0)	Martin & Martin 1994, (6)	Kurland 1996, (5)	Orr 2002, (0)	Greco 2003, (1)	Okudan 2004, (4)
Extrusion (P, T)	√		√		√	√
Shelling/ skinning (P, T)	√		√		√	√
Creation of draft angles (P, T)	√		√		√	√
Filleting, chamfering/ blending (P, T)	√		√		√	√
Creation and retention of ribs (T)			√		√	
Feature patterns (linear, circular) (T)			√		√	√
Sweeping profiles along curves (P, T)	√				√	√
Lofting (P, T)	√				√	√
Revolve (P, T)	√				√	√
Associativity (one way, two way) (T)			√		√	√
Cross sections (T)			√		√	
Offset sections (T)			√		√	
Isometric views (T)			√		√	√
Assembling parts (T)			√		√	√
Parametric relationships altering (T)			√		√	√
Complex blends (T)			√		√	
Installation and setup (T)					√	
Ease of use (P, T)	√	√			√	
Speed (P, T)	√	√			√	√
Reliability (P, T)	√					
Cost (T)		√				√
Number of mouse operations to complete a predetermined object model (T)		√				
Operating system (T)					√	
Interface/command structure (T)		√				
Animation (T)		√				
Rendering (T)		√				
Dimensioning (T)		√				√
Innovation (T)					√	
Support/educational materials (T)					√	√
Customization (T)					√	
Web awareness (T)					√	
Document management (P)				√		
Viewing and markup (P)				√		
Threaded discussion (P)				√		
Requirements capture (P)				√		
Product data management systems (P)				√		
Calendar and task management (P)				√		
Whiteboard (P)				√		
Project directory (P)				√		
File conversion facilities (P)				√		
Polls (P)				√		
Decision making tools (P)				√		
Audit trail (P)				√		

Table 1 Solid Modeler Comparison Criteria and Functions

Previous Studies of Solid Modeler Comparison (Author, year of publication, number of solid modelers compared)

US News and World Report), a web search was completed to document the solid modeler (i.e. SolidWorks, Inventor, ProEngineer, etc.) usage. Search on each school's website included solid modeler usage in any of its engineering design courses, focusing primarily on mechanical engineering. To do this, first Mechanical Engineering Department's home page was targeted and then curriculum listings as well as any available course descriptions or syllabi were reviewed. Course descriptions proved to be of little help since they are somewhat broad and do not go into detail about the course. However, if a course syllabus was accessible, it usually listed what software was used for the solid modeling portion of the course. If neither a course description nor a syllabus was available, the school's website search engine was turned to as the next resource. Then, the website was searched for direct hits on keywords such as SolidWorks or ProEngineer. This resulted in a listing of any web page (on the school website) containing those keywords. From this list, a course web page containing the information needed could usually be found. As the last resort, individual course instructors were emailed.

After gathering, all data were compiled on a spreadsheet with each school's name in order of ranking in 2002, the engineering design course number and name, software used in the course, as well as the respective website from which the information was collected. Of the 21 schools from which data were available, 11 use ProEngineer, 10 use SolidWorks, 2 use Solid Edge, 2 use Inventor, 1 uses Alibre, 1 uses Mechanical Desktop, 1 uses CATIA, and 1 uses MATLab (Okudan, 2004). After reviewing these data, three solid modelers that were at comparable price levels and relatively widely used, were chosen for comparison: SolidWorks, Solid Edge and Inventor. While ProEngineer was in fact the most widely used solid modeler, it was not included in the study due to its cost. At the time, the solid modeling package that was being used at Penn State was IronCAD. With IronCAD, four packages were included in the comparison study: SolidWorks, Solid Edge, Inventor and IronCAD.

Step 2) *Determine solid modeling functions to be compared.*

Selected functions for comparison include extrude builds, extrude cuts, filleting, associativity of the solid modeler, dimensioning, isometric views and creating 2D drawings of solid models etc. For the complete list of selected functions see the last column in Table 1. These functions were compiled based on the requirements of the Introductory Engineering Design teaching at Penn State.

Step 3) *Compile a training manual and a schedule for solid modeling learning for the functions determined in step 2.*

The four solid modeler companies SolidWorks Inc., Autodesk Inc., IronCAD LLC, and EDS were contacted at the same time to provide training materials for the comparison study. All companies responded with a collection of their educational materials. Then, all training materials received were reviewed for their adequacy in supplementing the design teaching for the Introductory Engineering Design course at Penn State. This process eliminated two of the solid modelers originally selected to be in the short list for comparison[1], because their educational materials were not found to be adequate for implementation or integration to the course.

Step 4) *Conduct user performance experimentation.*

For the remaining two solid modelers, a classroom experimentation was planned to compare their effectiveness on students' solid modeling learning and hence modeling performance. The experimentation involved the same instructor teaching two sections of the same Introductory Engineering Design course, with one software in one section, with the other software in another section during the same semester.

The pre-prepared training manual for each modeler was designed to take about 20 hours in class-work for each student. These in class work hours were planned as 10 two-hour sessions over the semester. Sessions were conducted in a computer laboratory as a part of the six-hour Introductory Engineering Design course. On the seventh week of the training two CAD quizzes were given to both sections on the same day using the same questions. Students were given two hours to complete both quizzes. First quiz was given to all students at the same time in each section. As soon as a student was done with the first quiz, second quiz was given. None of the students had to wait for any other to start the second quiz.

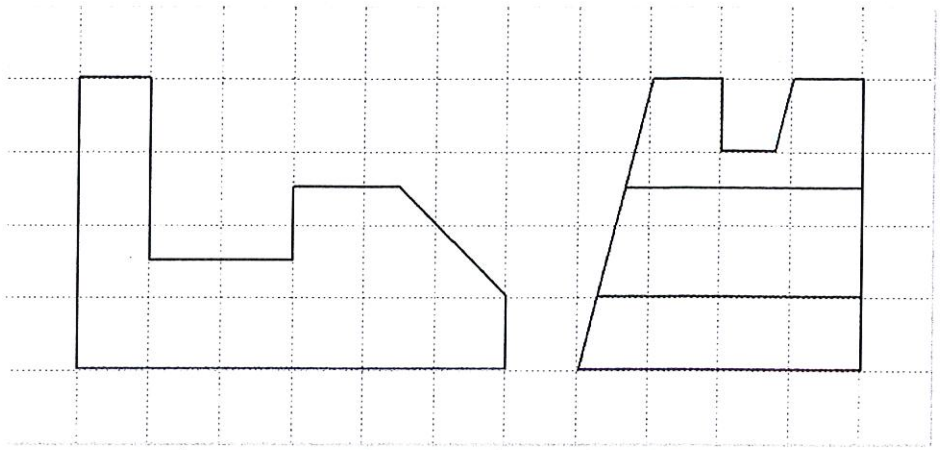

Figure 1 First quiz problem (Adopted from Bertoline et al.,1998, pp.353)

The CAD quizzes were given as practice quizzes three weeks before they completed their training manuals. Students were offered extra grades for participating in the study to motivate them for a high performance. Questions were designed to understand the student learning on the predetermined curriculum subjects[2], which include the software comparison functions. Two performance measures were used in this experimentation: 1) correctness and completeness of the solid modeling drawing (assessed by a performance grade between 0-1), and 2) time to complete the drawing in minutes. Figures 1 and 2 show the quiz questions respectively.

For both quizzes the following items were asked to be completed:

1. Create the 3D object using your solid modeler.
2. Create the standard multiviews and an isometric view on an A-size landscape paper.
3. Include scale information, your name and drawing name in the title block.
4. Complete dimensioning and print your work.

During the quizzes, students were not allowed to ask questions or talk to each other. Furthermore, they were asked to run only the solid modeler on their computer. Table 2 shows the results of this experimentation. The quizzes were taken by all students on identical computers in the same computer laboratory. The first section of students completed their quizzes between 12:20-2:20 pm, and the next section at 2:30 pm-4:30 pm. Students were not allowed to take the quiz questions with them when they were done.

Step 5. *Analyze User Performance Data Statistically And Conclude.*

Using Minitab™ Release 13.1, differences of sample averages for user performance and completion time for both quizzes were tested for their significance. Table 3 shows these data. As can be seen with the p values for all four two-sample t tests, differences in sample means were not found to be statistically significant. This means that for the functions that were the subject of comparison, both software deliver similar results with a similar average time for students to complete the same problems.

In fact, when data in Table 2 were analyzed, it is seen that with the exception of a few cases, users were able to complete both quiz problems correctly. This is reflected in the performance data for both samples mostly being 1.00 out of 1.00. However, while the sample means were not statistically significant, the time it took users to complete the quizzes had a spread for both solid modelers. Therefore, using Minitab™ Release 13.1, variance tests were conducted for completion time of quizzes.

When the hypothesis test for equality of variances between two samples for quiz 1 using an F-test is completed, sample variances were found to be significantly different. The test is conducted for 95% confidence level. Figure 3 shows the Minitab output with a p value of 0.031.

The significant difference in sample variances indicates a more homogeneous user performance data (similar in completion times) (in this case for software 2), in comparison to a more heterogeneous set (software 1). This might be a sign

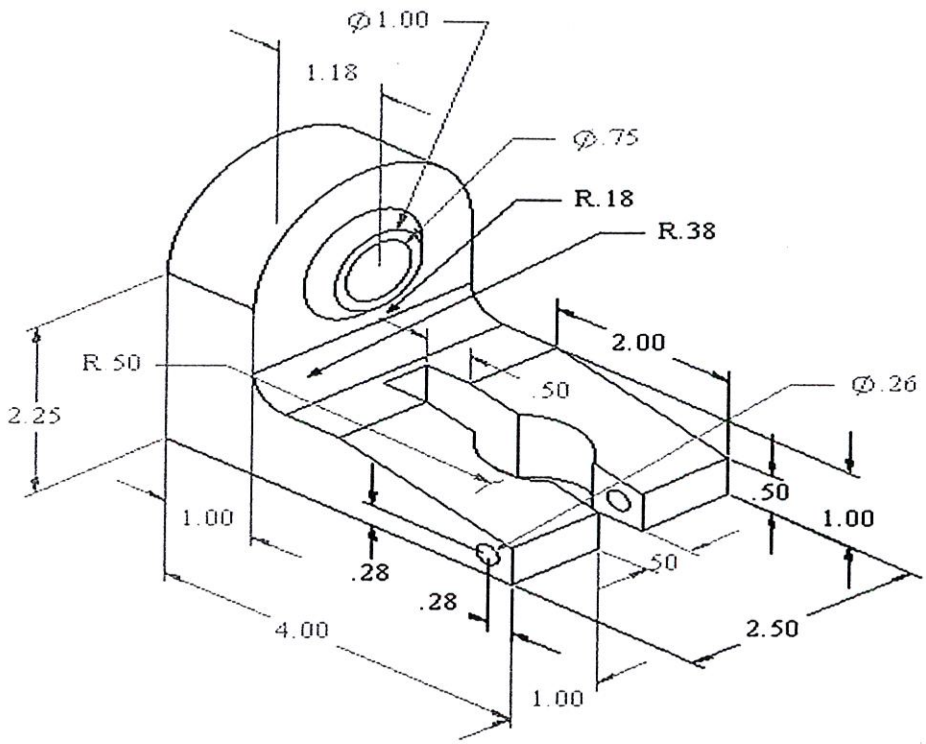

Figure 1 Second quiz problem (Adopted from Bertoline et al., 1998, pp.362)

Performance for Quiz1, Software1 PerQ1S1 (Grade 0-1)	Time Spent for Quiz1, Software 1 TimeQ1S1 (Min)	Performance for Quiz2, Software1 PerQ2S1 (Grade 0-1)	Time Spent for Quiz2, Software 1 TimeQ2S1 (Min)	Performance for Quiz1, Software2 PerQ1S2 (Grade 0-1	Time Spent for Quiz1, Software 2 TimeQ1S2 (Min)	Performance for Quiz2, Software2 PerQ2S2 (Grade 0-1)	Time Spent for Quiz2, Software 1 TimeQ2S2 (Min)
1.00	30	1.00	65	1.00	30	1.00	35
1.00	25	0.75	60	1.00	15	0.75	40
1.00	60	0.80	30	0.90	20	0.90	90
1.00	30	1.00	60	1.00	30	1.00	50
1.00	60	1.00	60	1.00	25	1.00	55
1.00	30	1.00	25	0.75	30	1.00	30
0.75	45	1.00	50	1.00	35	1.00	45
1.00	24	1.00	54	1.00	20	1.00	20
0.50	30	1.00	20	1.00	20	0.75	55
1.00	15	1.00	30	1.00	30	1.00	40
1.00	15	1.00	25	1.00	30	1.00	25
1.00	15	1.00	30	1.00	10	1.00	20
1.00	15	1.00	45	1.00	23	1.00	33
1.00	35	1.00	30	1.00	30	1.00	40
1.00	12	1.00	45	1.00	30	1.00	40
1.00	25	1.00	48	1.00	40	1.00	25
1.00	50	1.00	55	1.00	20	1.00	76
1.00	50	1.00	70	1.00	20	1.00	30
1.00	20	1.00	60	1.00	45	1.00	45
1.00	40	1.00	60	1.00	20	1.00	50
1.00	15	1.00	45	1.00	45	1.00	65
1.00	15	1.00	30	1.00	41	1.00	56
1.00	09	1.00	45	0.75	15	1.00	25

Table 2 User Performance Experimentation

T-Test	N	Mean	Standard Deviation	Result
Two sample T test for PerQ1S1 vs. PerQ1S2	23	0.967	0.114	Estimate for difference: -0.0065 95% CI for difference: (-0.0637, 0.0507) T-Test of difference = 0 (vs. not =): T-Value = -0.23 P-Value = 0.819 DF = 44 Both use Pooled StDev = 0.0962
	23	0.9739	0.0737	
Two sample T test for TimeQ1S1 vs. TimeQ1S2	23	28.9	15.4	Estimate for difference: 1.78 95% CI for difference: (-5.85, 9.41) T-Test of difference = 0 (vs. not =): T-Value = 0.47 P-Value = 0.640 DF = 44 Both use Pooled StDev = 12.8
	23	27.13	9.61	
Two sample T test for PerQ2S1 vs. PerQ2S2	23	0.9804	0.0653	Estimate for difference: 0.0065 95% CI for difference: (-0.0348, 0.0479) T-Test of difference = 0 (vs. not =): T-Value = 0.32 P-Value = 0.752 DF = 44 Both use Pooled StDev = 0.0696
	23	0.9739	0.0737	
Two sample T test for TimeQ2S1 vs. TimeQ2S2	23	45.3	14.9	Estimate for difference: 2.26 95% CI for difference: (-7.48, 12.00) T-Test of difference = 0 (vs. not =): T-Value = 0.47 P-Value = 0.642 DF = 44 Both use Pooled StDev = 16.4
	23	43.0	17.7	

Table 3 Statistical Analysis of Results

of users' different interpretations of GUI elements and hence related performance differences. For example, in this experimentation, higher variance in completion time data for software 1 could be seen as a result of a higher potential for software 1 GUI elements' less than uniform interpretations. However, normality of the two sample data should be investigated first before pointing at solid modeler differences. Figure 4 and 5 show Anderson-Darling normality tests for both samples.

As can be seen in Figures 4 and 5, for a 90% confidence interval both of the data sets follow normal distributions (p-value for TimeQ1S1= 0.029, and p-value for TimeQ1S2= 0.087). Thus the significant difference in variances cannot be dismissed.

When a hypothesis test for equality of variances between two samples using an F-test is completed for the second quiz problem, sample variances were not found to be significantly different. The test was conducted for 95% confidence level using Minitab. Figure 6 shows the Minitab output with a p value of 0.430.

Based on the statistical analysis presented above, in terms of time to complete the problem while no significant difference in sample means for both quiz problems, and no significant difference in variances for quiz 2 were found, due to the significant variance in time to complete the problem for quiz 1, software 2 is selected to be integrated to the engineering design curriculum. Because based on the multi-user experimental study presented above, software 2 was deemed to yield a more uniform user performance in terms of completion time when compared to software 1.

Step 6) *Repeat steps 1-5 in regular intervals.*

Because the application took approximately two years, the interval for repeating the SMECC cycle is determined to be two years. The new cycle has started in Spring 2004 semester.

Conclusion

Solid Modeler Evaluation and Comparison Cycle (SMECC), as a methodology that eliminates the limitations of previous solid modeler comparison studies is proposed and its application is shown in this paper. Steps of the cycle are:

Step 1) Develop a short list of solid modelers for comparison. In this study cost was used as a criterion to select a subset of solid modelers from

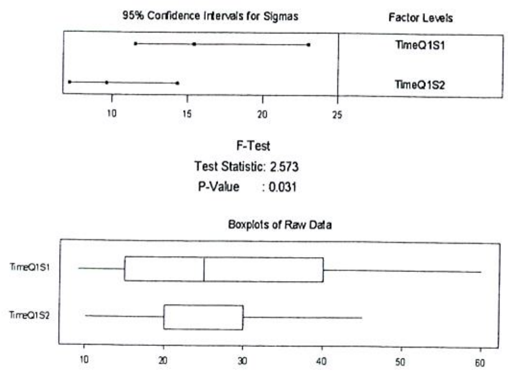

Figure 3 Variance Test Results for Quiz 1 Completion Time Data

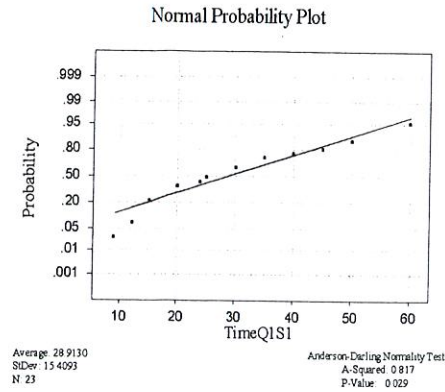

Figure 4 Normality Test for TimeQ1S1 Data

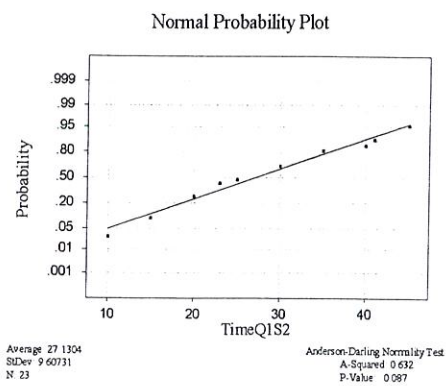

Figure 5 Normality Test for TimeQ1S2 Data

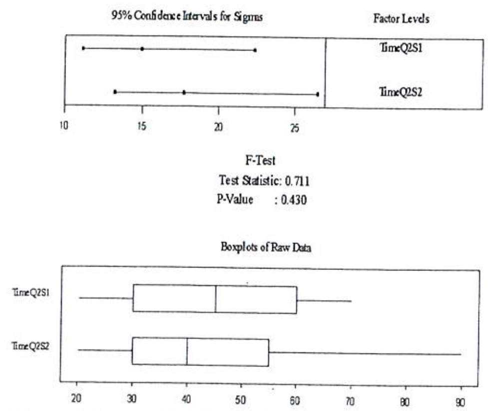

Figure 6 Variance Test Results for Quiz 2 Completion Time Data

the compiled list of top 30 engineering schools' choices, however, other criteria could be used for different situations. For example, existing computer hardware and/or platform might bring limitations, or availability of specific functions such as animation, might qualify or disqualify solid modelers from the short list.

Step 2) Determine the solid modeling functions to be compared. Function determination can only be done with a clear idea of what the solid modeler is going to be used for. For example, during the Introduction to Engineering Design course, for which the selection study was completed, multi-location design collaboration is not required, therefore, viewing and markup capabilities of modelers were not compared. Table 1 provides a comprehensive list of solid modeling functions to choose from based on potential needs.

Step 3) Compile a training manual and a schedule for solid modeling learning for the functions determined in step 2. A clear, concise, mistake-free training manual with adequate number of examples, and exercises is very important in solid modeling learning. Most solid modeler companies have educational branches that prepare and maintain these training manuals in print or on-line medium. However, based on the selection experience presented in this article it can be stated that there is a significant difference among manuals of different software for the same functions in terms of clarity, conciseness and the number of mistakes; therefore, educational materials should be carefully reviewed.

Step 4) Conduct user performance experimentation. While there are other ways of selecting software such as using one expert evaluating a number of software packages, different experts evaluating different software using the same set of criteria etc., for institutions where the modeler will be used by a large number of people with different backgrounds (like educational institutions), a multi-user performance experimentation should be completed. This experimentation reveals potential performance differences due to the different graphical user interface items (menus, icons, etc.), and hence a more equitable performance field can be established for users. If, however, there are published user performance studies available for the same set of modelers for the same set of functions, experimentation is not needed.

Step 5) Analyze the user performance data statistically and conclude.

Step 6) Repeat steps 1-5 in regular intervals.

This solid modeler evaluation and comparison cycle (SMECC) has been developed based on a comprehensive review of the previous solid modeler comparison studies, comparison criteria and functions. In addition, it has been applied at Penn State and the experience gained is explained above. Overall, SMECC overcomes limitations of previous solid modeler selection studies in the literature.

Because solid modeling is becoming the choice of designers instead of 2D CAD software, the set of outcomes of this study such as the compiled set of solid modeler comparison criteria, the methodology proposed and applied for solid modeling software comparison are expected to aid companies and design educators in making better design software selection decisions.

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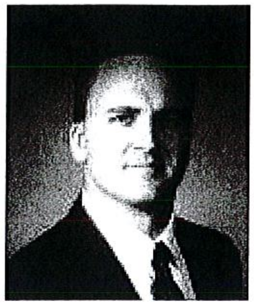
[1]The two solid modelers eliminated from the comparison study are not named, because the comparison methodology presented in this study is provided as a decision making tool for an objective and optimum solid modeler selection for specific uses. It is realized that different solid modelers will meet various customer needs at different levels. Therefore, software names were given in order not to mislead readers.

[2] CAD quizzes were not designed to measure their learning on revolves, sweeps and patterns functions. Because at the time of the practice quizzes, students were not done with those chapters. Furthermore, while they were done with the assemblies section of their manual, due to time limitations quiz questions did not include an assembly.

[Vice Chair]



Ted Branoff

Alice Y. Scales

Dr. Ted Branoff is an Associate Professor of Graphic Communications in the Department of Mathematics, Science and Technology Education at North Carolina State University. He received a bachelor of science in Technical Education in 1985, a master of science in Occupational Education in 1989, and a Ph.D. in Curriculum and Instruction in 1998.

Prior to joining the faculty at NC State, Ted was employed with Measurements Group, Inc. creating PC board layouts for strain gage instrumentation and with Siemens, Switchgear Division creating mechanical and electrical specifications for low voltage switchgear. A member of ASEE since 1987, Ted has been serving as chair of Professional & Technical Committees since 2002 and as Associate Editor in charge of paper reviews for the Engineering Design Graphics Journal since 2003.

His research interests include spatial visualization in undergraduate students and the effects of online instruction for preparing community college educators. Along with teaching courses in introductory engineering graphics, computer-aided design, descriptive geometry, and instructional design, he has conducted CAD and geometric dimensioning & tolerancing workshops for both high school teachers and local industry.

Dr. Alice Y. Scales, Ed.D., is an Assistant Professor at North Carolina State University, where she has taught since 1988. At NCSU, she serves as the Assistant Department Head of the Department of Mathematics, Science, and Technology Education and Coordinator of the Graphic Communications Program. She received her B.S. in Science Education in 1965, her M.Ed. in Industrial Arts Education in 1983, and her Ed.D. in Occupational Education in 2000. Dr. Scales has taught students from the Middle Grades level to adults and taught in the Wake County Public Schools for 11 years and at Wake Medical Center for three years. While teaching in Wake County, she taught a variety of subjects and was involved in the writing of several curriculum projects. A member of the Engineering Design Graphics Division of ASEE since1989, she has served as an officer in a variety of professional organizations over the years. She has presented papers at the EDGD Midyear Meeting, the ASEE Annual Conference, and the ASEE Southeastern Regional Conference. At NC State University, she teaches introductory engineering graphics courses that include CAD, desktop publishing, and web site development. She has conducted research in the areas of teaching engineering graphics and CAD, and program assessment. She was awarded the honor of being named a Faculty of Distinction by AutoDesk, Inc. in 2000 for her web-based tutorials for AutoCAD Release 14.

[Director of Technical & Professional Committees]

Nancy Study

Dr. Nancy Study is an Assistant Professor in the Department of Engineering and Technology at Virginia State University where she teaches a variety of engineering and architectural graphics courses. She has presented at several EDGD and ASEE meetings on topics including haptics, visualization, and assessing and improving the visualization skills of minority engineering and technology students and is also an active author and researcher.

Nathan W. Hartman

Dr. Nate Hartman is an Assistant Professor in the Department of Computer Graphics at Purdue University where he currently teaches undergraduate courses in engineering graphics, 3D solid and surface modeling, graphics standards and documentation, and product data management. He also teaches graduate course covering the foundational elements of computer graphics and measurement and evaluation. His academic interests include the use of constraint-based CAD tools in the design process, the development of expertise and knowledge in the use of computer graphics tools, spatial visualization ability, and the development of graphic science as a discipline. Nathan holds a Bachelor of Science in Technical Graphics and a Master of Science in Technology from Purdue University, and a Doctorate in Technology Education from North Carolina State University.

Dr. Hartman has worked for a variety of companies in using and integrating computer-aided design (CAD) tools into the engineering design process through the development of custom training applications and materials. He worked for RAND Worldwide as a Senior Technical Training Engineer where he taught courses for corporate clients and developed customized training curricula. Nate also provided on-site technical support for larger clients during their new product development stages and during their installation and configuration of product data management (PDM) tools. He has also worked for Caterpillar in the large engine design group and for Fairfield Manufacturing in the tool design and fixtures group.

[Director of Zones]

Patrick E. Connolly

Pat is an Associate Professor in the Department of Computer Graphics Technology with Purdue University at West Lafayette, Indiana. He received his Bachelor of Science degree in Design and Graphics Technology and Master of Science degree in Computer Integrated Manufacturing from Brigham Young University in Provo, Utah. He is presently working on a Doctorate in Educational Technology at Purdue University. Pat has been teaching at Purdue since 1996, and has received several awards for teaching excellence and academic publications, including the Oppenheimer Award in 1997 and 2004, and the EDGD Chair's Award in 1998. He has served as a member of the EDG Journal Review Board for a number of years, as acting Journal Editor, and as Program Chair for the 2002 Midyear meeting in Indianapolis. He will serve as the EDGD Program Chair for the ASEE Annual Conference in Chicago in 2006. Prior to entering academia in 1996, he worked for twelve years in the aerospace and computer software industries and has extensive experience in CAD applications and design, CAE software support, and customer service management. His interests include solid modeling applications, visualization techniques, learning styles, e-enterprise, and distance learning. He is a member of the Gamma Rho Chapter of the Epsilon Pi Tau honorary society.

David Kelley

Dr. David Kelley is an Associate Professor in the Department of Engineering and Technology at Central Michigan University. He is a graduate of the University of Southern Mississippi (BS, 1990; MS, 1992) and Mississippi State University (PhD, 1998). Prior to joining Central Michigan University, he served on the faculty in the Department of Computer Graphics Technology at Purdue University. Dr. Kelley has also served as a faculty member at Western Washington University, Oklahoma State University - Okmulgee, Northeastern State University (Tahlequah, Oklahoma), Northwest Mississippi Community College, and Itawamba Community College (Fulton, Mississippi).

Dr. Kelley's primary teaching responsibility is in the area of Industrial Technology Management and Computer-Aided Design. His computer-aided design experience includes AutoCAD, CATIA, I-DEAS, Pro/ENGINEER, Solid Edge, and SolidWorks. In addition to his CAD teaching background, he has taught courses in computer-aided manufacturing, quality control, animation, and engineering design graphics. He is a member of ASEE, Epsilon Pi Tau, and NAIT. He is a Certified Manufacturing Technologist through the Society of Manufacturing Engineers. Dr. Kelley's research and scholarly interests include parametric design, collaborative engineering, and technology education. He is the author of the Pro/ENGINEER Instructor series published by McGraw-Hill.

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Resolution

Frank M. Croft, Jr.
2004 Mid-year Meeting Resolutions Chair

Whereas the 59th Annual Engineering Design Graphics Division Mid-Year Meeting has occurred at the Woodlands Conference Center in beautiful Williamsburg, Virginia, where our hosts, Barry Crittenden and pat Devens, have provided us with a suitable forum for the exchange of ideas, concepts, methodologies, and conviviality;

And, whereas Barry Crittenden and Pat Devens as Co-General Conference Chairs and Bob Chin of Eastern Carolina University and Leo Lefrance as Conference Program Chairs have attracted scholars from across the United States who presented excellent and thought provoking papers;

And, whereas Naomi Flythe and Susan Hilton served as Conference Coordinators,

And, whereas, the conference sponsors, AutoDesk, Thomas Learning, Schroff Development Corporation, SolidWorks, Delmar Publishing and McGraw-Hill Publishing provided the support to ensure that a quality conference was held;

And, whereas the breaks and social gatherings were hosted the aforementioned sponsors;

And, whereas, the Division had a wonderful afternoon of touring Colonial Williamsburg guided by Alice Scales and Barry Crittenden

And, whereas the spouses and families of our division members have enjoyed special tours, family events, and ambiance of the Colonial Williamsburg area;

Now therefore it is resolved that the Engineering Design Graphics Division of the American Society for Engineering Education extends its thanks and appreciation to the aforementioned organizations and individuals.

Copies of this resolution shall be transmitted to theses individuals and shall be spread on the records of the division.

[Standards Corner]

Patrick J. McCuistion
Ohio University

In the 15 years I have been attending the Y14 meetings I have attempted to present what I have learned to the engineering education community via workshops at the ASEE annual and mid-year meetings and this Standards Corner. With my increased responsibilities in Y14 committees (memberships in 9 different committees) there is not much time to devote to ASEE activities. My association with other EDGD members is very much missed.

I sincerely regret that my institution does not fund my Y14 activities and only funds EDGD meetings when I present a paper. This forces me to choose between two activities that I really enjoy. I have chosen Y14 committees because that is where I can make the biggest impact.

Not all is gloom and doom. I'm very pleased to report that Ed Evans from Penn State Erie has attended the last three Y14.5 Dimensioning and Tolerancing meetings and appears to have some funding to attend more meetings. He attended his first Y14.8 Castings, Forgings and Molded Parts Drawings meeting this fall. The information he learns and associations he makes at the meetings should allow him to assume the EDGD Standards Chair position and write regular reports for this Standards Corner. Please join me in encouraging Ed to keep the embers burning.

Edward R. Evans, Jr.
Penn State University Erie, The Behrend College

Throughout my professional career, I have had a desire to become involved in the national standards for engineering graphics, ASME Y14. In February of this year, I took the plunge and attended my first meeting of subcommittee 5, the group responsible for dimensioning and tolerancing. The subcommittee is deeply immersed in the long, and sometimes tedious, process of revising the standard. The current standard, dated 1994, was reaffirmed in 1999. Because Y14 rules stipulate that action to revise, reaffirm or withdraw a standard must be undertaken every five years, it is anticipated that the current standard will be reaffirmed again in 2004.

The revision of each section of the standard is being performed by a "working group" which is headed by a subcommittee member who is known as the "section sponsor." The working group consists of subcommittee members and the support people who are typically long time visitors who were invited to be part of the working group. Vacant subcommittee seats are often filled by the appointment of one of the support people to the subcommittee. The Y14.5 subcommittee convenes two or three times a year to work on the standard. The working groups typically meet prior to each subcommittee meeting in addition to two other times throughout the year. The October meeting of the Y14.5 subcommittee was the twenty-third meeting in this revision cycle. Clearly, a lot of time and effort goes into the preparation of this national standard. This revision promises to have many new concepts that will expand the practice of dimensioning and tolerancing.

This year, I have attended three Y14.5 subcommittee meetings. I have met many individuals who bring many years of experience from a variety of industries to the committee. My contact with these folks has lead to my appointment to the Y14.8 Castings, Forgings and Molded Parts Drawings subcommittee. This subcommittee is smaller than the Y14.5 committee, but the breadth of knowledge and experience brought to the subcommittee by its long standing members is extensive. I am honored to have been appointed to this committee and I plan to participate to the best of my ability. The next Y14 meetings will be held in Minneapolis in April. You are invited to attend the meetings to experience them for yourself.

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Please visit the competition website at:
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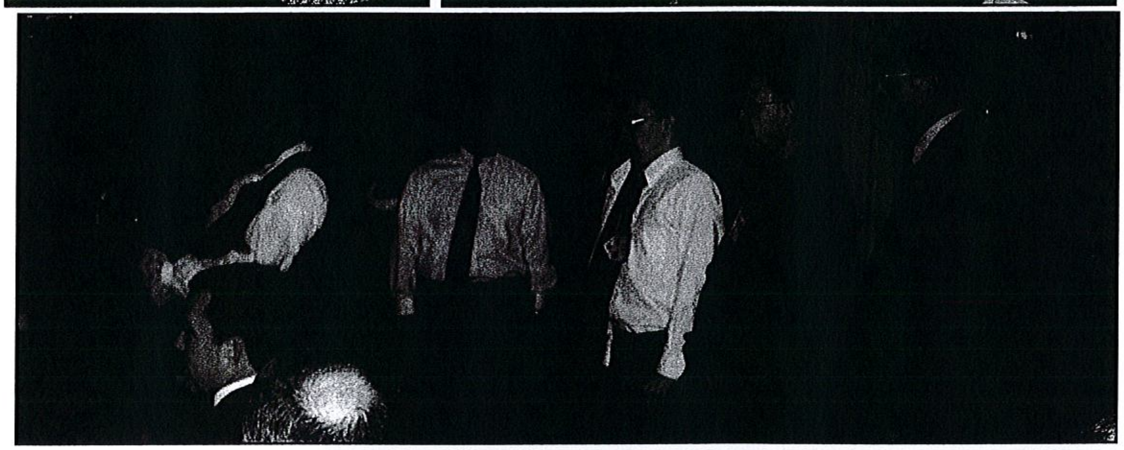

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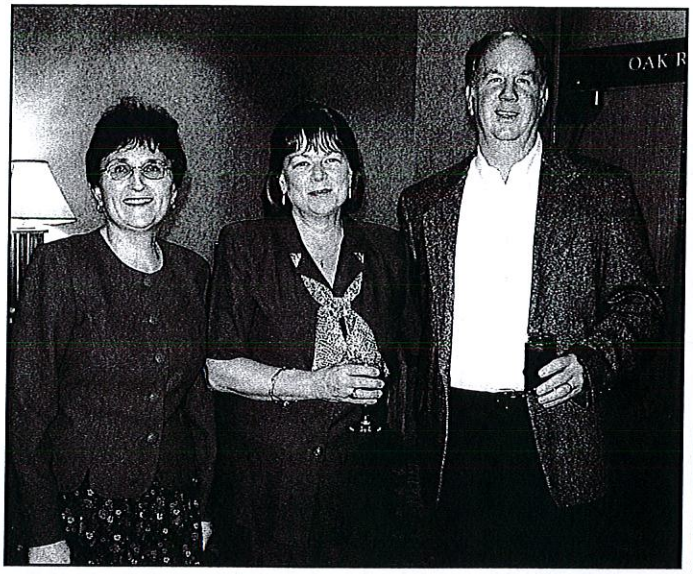

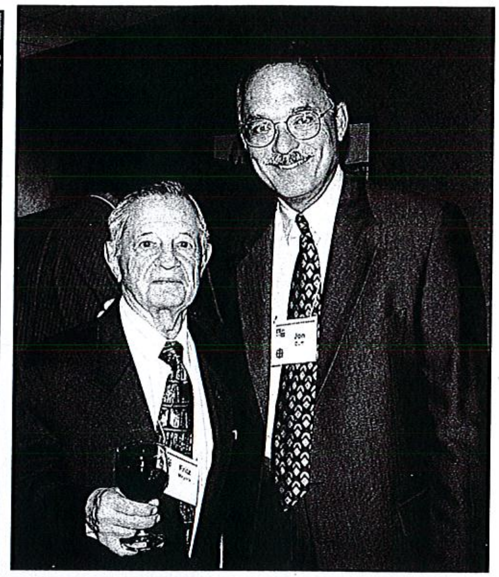

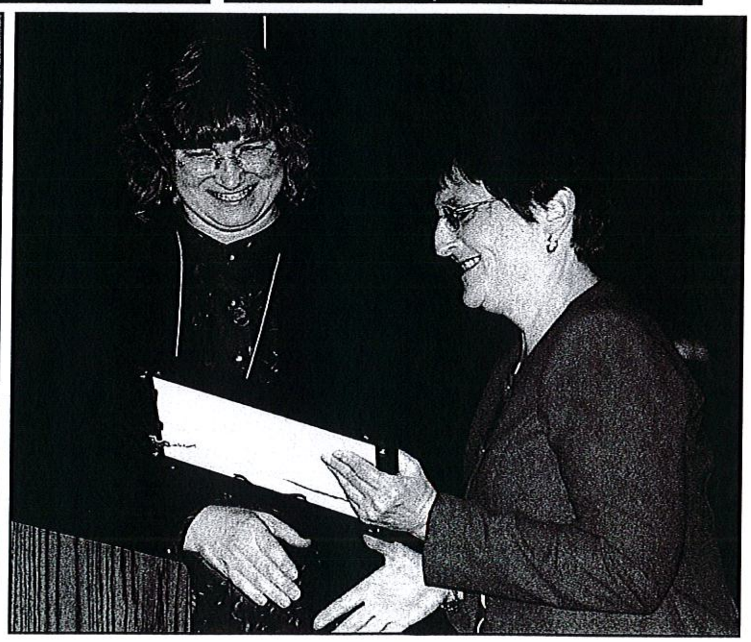

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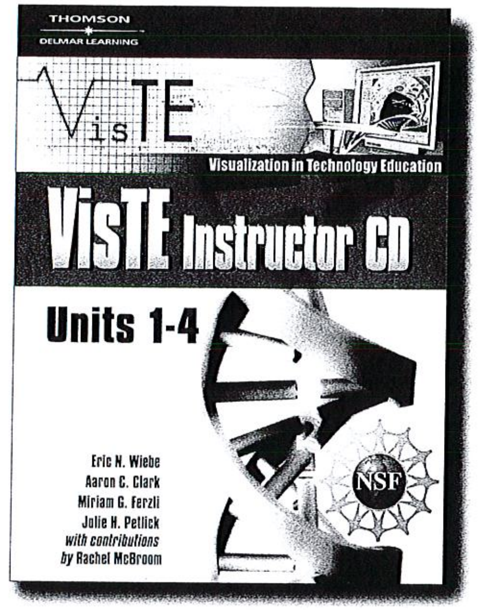

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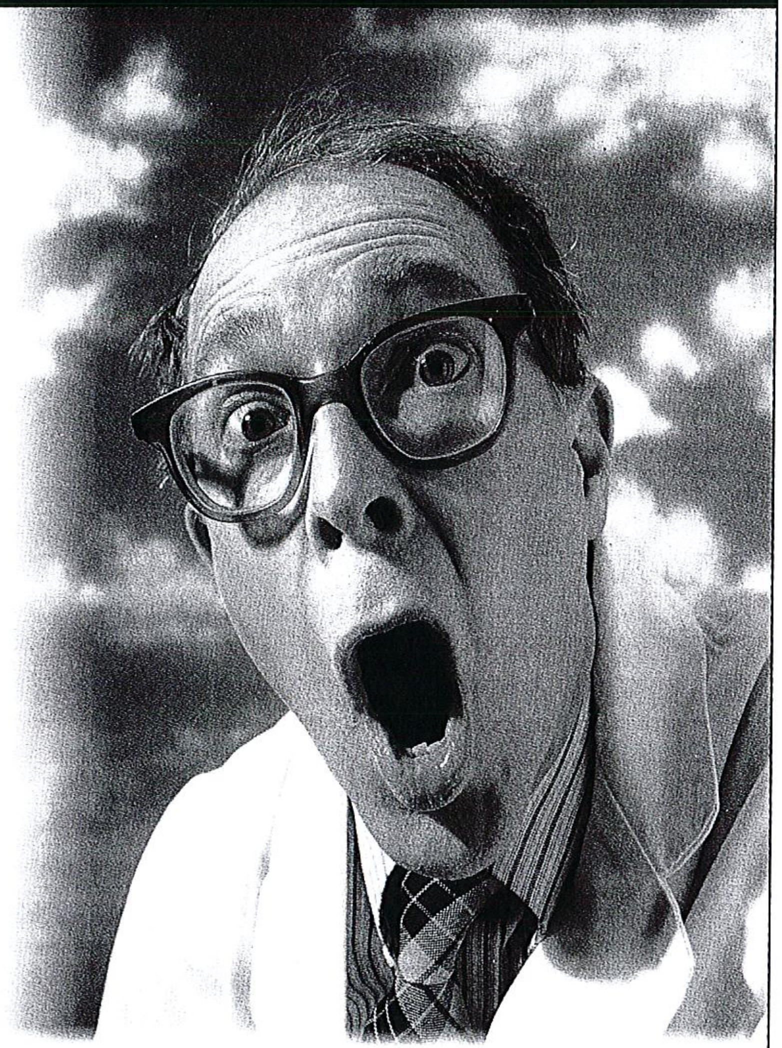

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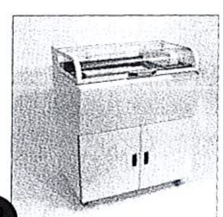

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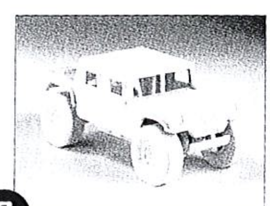

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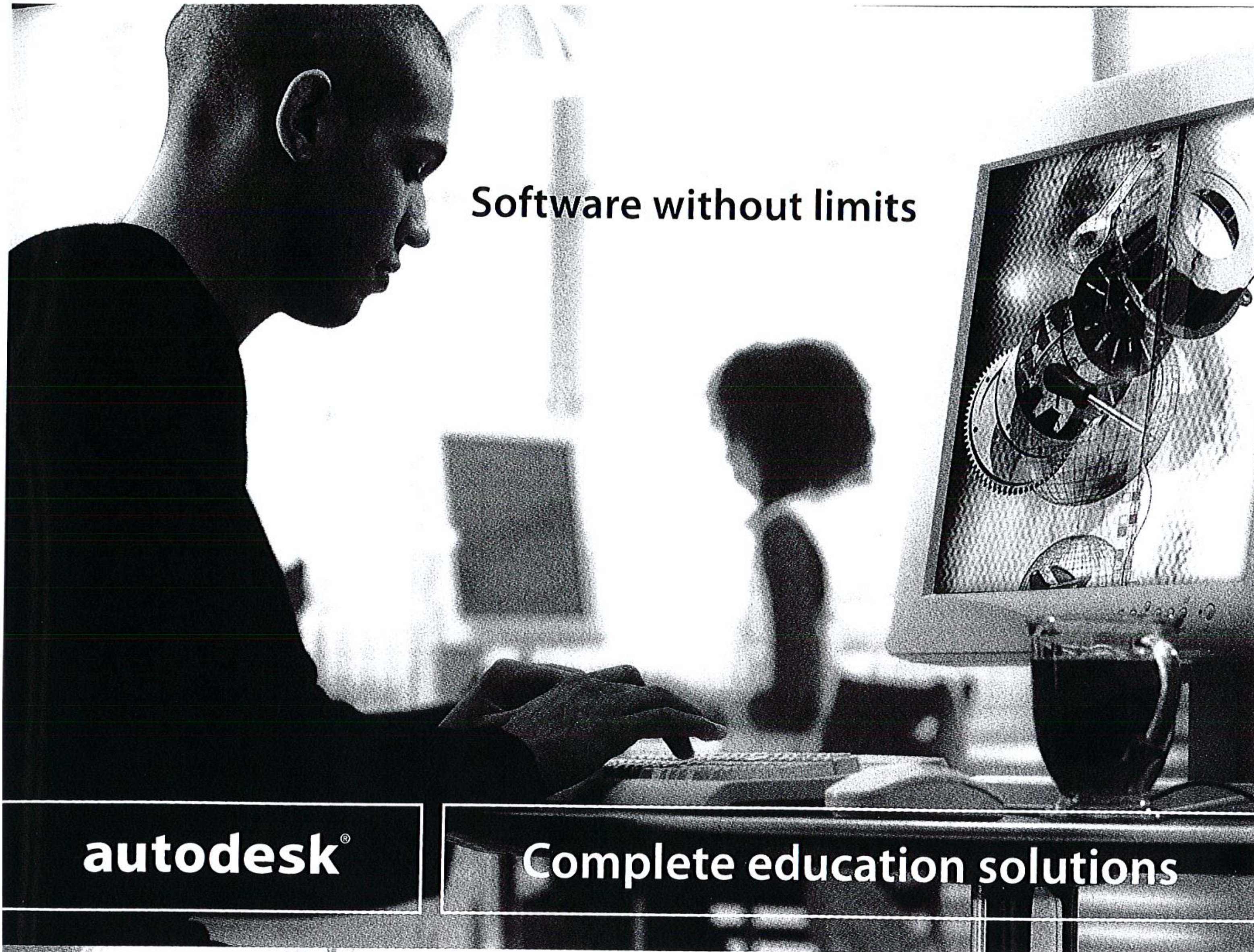

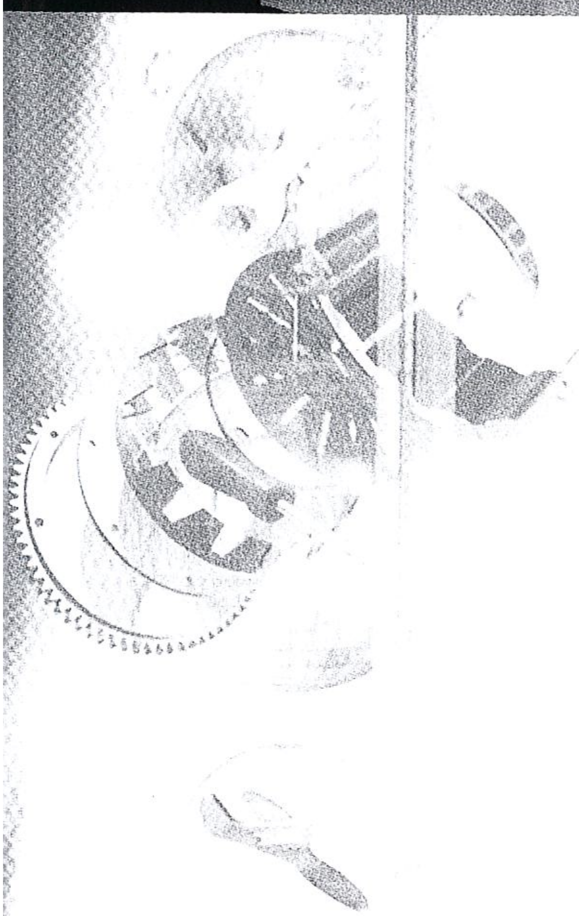

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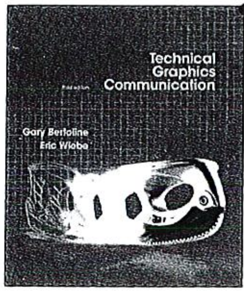

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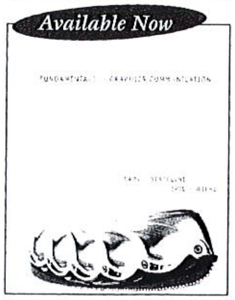

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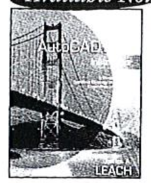

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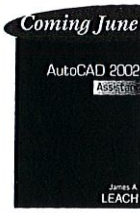

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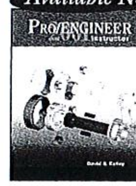

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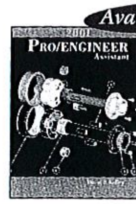

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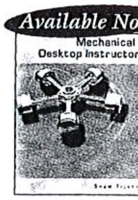

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