26. Computer-Aided Design Technology

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Introduction

My part of the Rockford project focused on applying school mathematics in the study and using computer-aided-design (CAD) technology. We also conceived the idea that CAD could be used as a showcase tool to advertise and promote potential careers in engineering and technology. The implementation phase of our effort required integrating CAD into middle and high school mathematics through teacher training, which would lead to learning opportunities for students. The broad objectives were to (1) provide hands-on training in CAD with the aim of inspiring teachers to blend technical thinking and problems into mathematics education and (2) provide a basic orientation in CAD and its downstream applications, thereby encouraging teachers and if possible career counselors to encourage student exploration of engineering technology as a career choice. A teaching and learning module that integrated CAD into selected school mathematics topics was also developed.

This paper summarizes the activities that were conducted in a two-day workshop and the development of an instructional module. CAD was also used in a career workshop. (For details see Balamuralikrishna & Mirman, 2002.)

Lines of Communication Between Schools and Colleges – The Need

A significant proportion of the population switches career plans during and after the postsecondary experience, but most young people map out their initial career path by the time they enter their final year in high school (Occena, Chen & Lammers, 1996). Professional bodies such as the American Society for Engineering Education (ASEE) and the Society of Manufacturing Engineers (SME) have recently embarked on initiatives geared to promote engineering and technology in K-12 education (Cohen, 2001; Hogan, 2001). The rationale is to "catch them young" and induce the best talent to pursue a career in engineering or technology. ASEE's President Jakubowski (2002) has warned that "if the United States does not start closing the gap in student achievement in science and mathematics, the country runs the risk of becoming disadvantaged in the worldwide economy" (p. 41). His faith in this proclamation was demonstrated by the introduction of an initiative called the ASEE Center for Best Practices in K-12 Science and Math Education. The College of Engineering and Engineering Technology at Northern Illinois University has joined ASEE in this effort.

Attracting good first-year students requires a sustained, multifaceted effort. The purpose of a recruitment program is to increase the visibility of the institution's offerings throughout the community and to establish ties with regional middle schools, high schools, and community colleges (Balamuralikrishna & Mirman, 2002).

Why Use CAD to Promote Careers?

CAD software facilitating the creation of both 2-D drawings and 3-D solid models is generally available in postsecondary institutions that offer degrees in technical disciplines. In fact, such software is available in many high schools, although the number of licenses (seats) may be limited. The technology offers a safe, inexpensive way to open minds to the world of creativity that is embraced by both engineering and technology. Students of technical graphics (faculty members included) will readily admit their excitement upon creating their first 3-D solid model on the computer and watching it spin on the computer monitor. (A solid model is a three-dimensional, realistic representation of an object part or an assembly of parts.) Solid-modeling technology has been popular in industry for the past 10-12 years.

Before the era of 3-D CAD, engineers relied extensively on two-dimensional images that were created on paper or its equivalent. When writing on a flat surface, one is restricted to working on a plane that has two dimensions, width and height (x and y in a mathematical sense). A CAD system is physically unrestricted because the input data is based on coordinate geometry, and a computer can deal with a three-coordinate system (x, y, z) almost as easily as the (x, y) system.

The applications of CAD offer an impressive array of potential showcase material. Technologies such as rapid prototyping, computer-aided engineering analysis, and computer-aided manufacturing generally depend on the availability of a solid model as a starting point. Computer-aided engineering analysis can be complex material for an audience that includes teachers from a wide range of disciplines, and computer-aided manufacturing can involve additional time, safety, and cost issues. On the other hand, rapid prototyping is an exciting, relatively new technology that is quite easy to learn and comes with minimal safety issues. This process makes use of the data file that is part of a solid model and proceeds to build a part, layer by layer, with the required human intervention being limited to a few clicks of a computer mouse and strokes of the keyboard. The result is a tangible, realistic looking prototype that can convey a sense of touch and instill a sense of fulfillment as users see their design ideas moving toward reality (Cooper, 2001). Rapid prototyping machines are becoming common in every college CAD laboratory. Although solid modeling is exciting, it is essential for the CAD user to learn the basics of engineering design, engineering graphics, and CAD in two dimensions. This was the driving force behind the concept of conducting a CAD skills workshop for teachers.

Table 26.1 Timetable for Day 1 of CAD Skills Workshop

Time-Period	Activity
8 - 9 a.m.	*One who dares to teach should never cease to learn – John Cotton Dana* Introductions What is it? - An exercise in communication ***OR*** an exercise in frustration?
9 - 10 a.m.	*All that I've learnt in life* Background information exercise, selected State of Illinois learning standards & the potential for blending CAD into school mathematics
10 - 11 a.m.	*A journey of a thousand miles starts with a single step – Unknown* Introduction to CAD software, the SilverScreen design package
11 a.m.-12 p.m.	*Begin with the end in mind – Steven Covey (In his "Seven Habits of Highly Effective People")* The importance of setting up your drawing screen - Drawing setup commands The story of "My first CAD drawing"
12 - 1 p.m.	*A hungry man is an angry man – Mr. Shetty (Author's former colleague in a shipyard in India)* Lunch – Yes!!! (Working lunch, CAD lab continued)
1 - 2 p.m.	*A picture is worth a thousand words…provided it's the right picture! – adapted from an old Chinese saying* Who was Gaspard Monge and how did he open new doors in technical communication/CAD? Spatial visualization exercise
2 - 3 p.m.	*An ounce of practice is worth tons of theory - Unknown* Problems to be solved using CAD techniques
3 - 4 p.m.	*The fun has just begun!* More problems to be solved using CAD

Workshop

The two-day workshop aimed at encouraging Rockford area middle and high school teachers to integrate CAD into their subject areas to enhance the learning of mathematics and science. This was the first exposure to CAD for nearly all teachers. The teachers represented a wide array of disciplines, including English, science, and mathematics. The workshop's goal was to help teachers communicate ideas embedded in engineering and technology to their students. It was necessary to buy software, the SilverScreen™ package, but almost any CAD software package available today would have worked.

One of the first concepts presented to the teachers was the problem of communicating the shapes of real-world, three-dimensional objects on a two-dimensional writing instrument (Schoonmaker, 2003). Participants were asked to match isometric pictorials of objects with their corresponding multi-view drawing. Jensen and Hines (1994) have created useful worksheets for this activity. The concept of coordinate geometry in two-dimensions was next addressed. Participants were asked to pencil sketch a two-dimensional shape defined by a series of points whose (x, y) coordinates were provided in table format. They then transferred the sketch to the computer. Teachers were pleased to see that coordinate geometry, which is a staple in their mathematics curriculum, provided the basis for CAD data input. Further application of CAD skills was introduced using a problem-solving approach. Then the teachers learned how to integrate CAD into middle and high school subjects.

As a capstone experience, participants worked in teams to create a two-dimensional drawing that could be used to produce paper carts, as described by Carruth, Peterson, and Chaney (1997). The raw materials needed were paper (manila-folder quality), two pencils, four paper clips, and a piece of string. The tools required for the project, besides CAD software, were a pair of shears and a straightedge. The teachers created the drawings with minimal help from the instructor. The teachers were excited to learn that with a little imagination they could adapt the paper-cart activity to explore various facets of manufacturing, including statistical distributions (Carruth, Peterson & Chaney, 1997). The schedule of activities for the workshop is provided in Tables 1 and 2.

Table 26.2 Timetable for Day 2 of CAD Skills Workshop

Time-Period	Activity
8 - 9 a.m.	CAD Laboratory More draw, edit and display options
9 - 10 a.m.	CAD Laboratory continued True shape description of objects
10 - 11 a.m.	Solving heights and distances problems from traditional trigonometry employing CAD methods
11a.m.-12 p.m.	CAD Laboratory Solid modeling
12 - 1 p.m.	Lunch Break – Yes!!! *In the United States anybody can grow up to become a teacher; it's just one of the risks one takes in life - adapted from Adlai Stevenson* CAD Q & A session (friendly quiz)
1 - 2 p.m.	*Those who can, do; those who can do more, teach - Unknown* Solid modeling continued
2 - 3 p.m.	Designing and constructing paper carts – potential student activity
3 - 4 p.m.	*The great aim of education is not knowledge but action - Herbert Spencer* Testing paper carts – potential student activity Evaluations, wrap-up

Instructional Module

In Illinois, K-12 education is largely standards-based. The availability of state standards for learning simplified the task of writing the module (www.isbe.net/ils/Default.htm).

The instructional module consisted of Lesson 1, "Plane Geometry – Creating Familiar Two-Dimensional Shapes and Estimating Areas," and Lesson 2, "Employing Computer Aided Design (CAD) to Solve Problems Involving Heights and Distances." Lesson 1 could be used in either middle or high schools with minor adaptation. Lesson 2 was strictly for use at the high school level. CAD was integrated into these lessons as appropriate. The basic purpose was to introduce students to the technology of computer-aided design while making use of mathematical concepts that were typically covered at that particular level of study. Students would need a prior knowledge of applying mathematical formula to compute areas created by enclosed 2-D shapes to complete Lesson 1. Also, they should have prior knowledge of solving problems related to heights and distances, using trigonometry, to complete Lesson 2. The module would allow students to experience how computer-aided design enables calculating areas of 2-D shapes and solves typical trigonometry-based problems involving heights and distances through the application of full-scale vector graphics.

Lesson 1 highlights

The Illinois state educational standards driving the content of Lesson 1 are (www.isbe.net/ils/math/mag6.html, www.isbe.net/ils/math/mag7.html):

IL-6.C	Compute and estimate using mental mathematics, paper and pencil methods, calculators and computers.
IL-7.A	Measure and compare quantities using appropriate units, instruments, and methods.
IL-7.A.4b	Apply formulas in a wide variety of theoretical and practical real world measurement applications involving perimeter, area, volume, angle, time, temperature, mass speed, distance, density and monetary values.

The students learned the basics of CAD through use of the SilverScreen™ software. They could model a two-dimensional situation using either the U.S. Customary or the SI units. The lesson focused on creating regular 2-D shapes, such as a triangle, rectangle, and circle, precisely to specifications and used problems to demonstrate the use of CAD in engineering applications through problems. Finally, the module included a set of activities (assignments) to be completed by the students with minimal guidance from their teachers. The learning premise was that if students followed the lecture material and completed the sample problems, they should have no undue difficulty in completing the assignment problems. A sample assignment problem follows:

> The surface of an aluminum metal sheet has the shape of an equilateral triangle. The base measures 525 mm. What is its area? Solve the problem using CAD and state your answer specifying correct units. Also, determine the altitude (height) of the metal sheet in mm. (Schaaf, 1963)

Schaaf also provided several other appropriate examples of problems that could be adapted for CAD usage and are strongly recommended for further investigation. The reader will recognize that problems of this nature are not limited to the cited sources; similar problems can be found in numerous textbooks dedicated to school mathematics.

Lesson 2 highlights

The state educational standards driving the content of Lesson 2 are (www.isbe.net/ils/math/mag7.html):

IL-7.C.4a	Make indirect measurements, including heights and distances, using proportions (e.g., finding the height of a tower by its shadow).
IL-7.A	Measure and compare quantities using appropriate units, instruments, and methods.
IL-7.A.4b	Apply formulas in a wide variety of theoretical and practical real world measurement applications involving perimeter, area, volume, angle, time, temperature, mass, speed, distance, density and monetary values.

Students should have completed Lesson 1 before starting Lesson 2. Complete step-by-step tutorials to solve the following problems were included as part of teacher presentation material:

1. What is the angle of elevation of a tower 20m high from a point 80m away?
2. Using a pair of binoculars, an ornithologist is observing birds that are resting on a cliff. She is standing 100m away from the cliff. Ignoring the height of the ornithologist, find by CAD drawing the heights of the birds being observed when her line of sight makes angles of 15^o, 30^o, 45^o, and 60^o with the horizontal.
3. A surveyor standing 50m from a cooling tower measures the angle of elevation of the top as 31^o. What is the height of the tower if the measuring instrument itself is 1.5m above the ground?

The following assignment problems were included with the expectation that students would solve these with minimal guidance from their instructor:

1. A boy of height 1.75m is measuring the heights of trees in the school grounds. He stands 24m from a tree and measures the angle of elevation as 42^o. Calculate the height of the tree (from ground level to treetop) as accurately as possible.
2. At a certain time during the day, the shadow (on the ground) of a vertical 75 foot pole is 100 feet long. What is the angle of elevation of the sun?
3. A tree located at a distance of 20m from a house is being chopped down. The angle of elevation of the top of the tree as measured from a first floor window is 44^o. Is it safe for the tree to fall in the direction of the house?

The problems included in the module encompass various levels of mental stimulation as defined in Bloom’s Taxonomy, which includes knowledge, application, analysis, and synthesis. For example, the preceding assignment problems address the knowledge and application of trigonometry. In addition, problem 3 requires analysis.

Results and Conclusion

Participants of the CAD workshops provided very favorable feedback. In particular, the teachers with a science, mathematics, or technical background were able to acquire the skills rather quickly. The teachers appreciated the hands-on approach used to deliver instruction. Many of them indicated that they would like to integrate CAD into their lesson plans based on what they learned during the workshop. Nearly all of them also noted that the activities were clearly tied to the Illinois State Board of Education teaching standards. Teachers are beginning to experience positive results in the classroom, in the form of increased levels of student enthusiasm, curiosity, and problem-solving ability. It appears that career counselors also have a better understanding of CAD and its critical role in engineering and technology. Both teachers and counselors strongly emphasized that this workshop enabled them to acquire confidence on this subject.

Engineering and technology programs have historically enjoyed considerable popularity among high school students. By actively including engineering applications in high school subjects, we may exploit the abundant, innate technical aptitude of students and encourage them to pursue science and mathematics more seriously. The experiences described here should encourage engineering and technology faculty to employ CAD as a marketing tool for increasing the visibility of engineering and technology programs. As CAD programs become more user-friendly and versatile, more teachers are likely to pursue workshops and basic orientation in this discipline. Middle and high school educators are close to the students colleges and universities wish to attract, and there would be mutual advantage in teachers and engineering and technology faculties finding new lines communication with one another.

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