Examining the Benefits of a Self-Taught Solid Modeling Course

Douglas H. Baxter

Rensselaer Polytechnic Institute

Introduction

All engineering students at Rensselaer Polytechnic Institute are required to take a one-credit course in solid modeling. This course, Engineering Graphics and Computer Aided Design (EG&CAD) teaches the skills of using a solid modeling system to create parts, small assemblies, and documentation. More importantly, EG&CAD also emphasizes the use of vectors in creating solid models and thereby provides students reinforcement of their linear algebra knowledge. The students normally take EG&CAD during their freshman year and then have the opportunity to use solid modeling in their sophomore and senior design projects as well as some special topic electives. In addition, several other courses are now using solid models as a way to demonstrate fundamental principles[2]. With an increasing dependence on solid modeling skills required, it is imperative that the course content in EG&CAD be effectively delivered and absorbed.

Finding the teaching staff to run EG&CAD for 750-800 students/year has always been a challenge. EG&CAD runs fifteen to twenty sections each semester; concerns about equality of instruction and evaluation between the sections always existed. Over the last nine years, several methods of instruction and teaching material have been developed to help ensure the uniformity of the learning experience for the students[3][4][5][7]. EG&CAD is run with one faculty member as course coordinator. A graduate student conducts laboratories with two additional student helpers. The graduate students are assigned to the course coordinator from the departments in the School of Engineering. The two student helpers are generally undergraduate students. The course coordinator hires the undergraduate students; these undergraduate students are identified as having done extremely well in EG&CAD. This method of supplying teaching staff for EG&CAD has been very successful over the last nine years. The greatest difficulty is the turnover of the graduate students. Graduate students are assigned on a semester basis; each semester requires extensive training to prepare the graduate students to teach the course.

Course Pedagogy

EG&CAD is taught with a series of twelve one hour lectures over a fourteen week semester[1][3][4]. The first six weeks are spent learning how to create solid models of parts, one week is spent on assemblies of parts and the remaining five weeks are spent on creating engineering drawings. Students also create hand sketches of parts creating both isometric and orthographic projections. An additional textbook[6] is used to supplement

the hand-sketching portion of the course. The last two weeks of the semester are dedicated to work on a final project. The final project consists of a small assembly that students create as a solid model and then document with a collection of engineering drawings. Each of the twelve lectures has an associated laboratory session where students work problems based on the lecture material. The laboratory sessions are two hours long. As EG&CAD is a one credit course, no additional work is assigned outside the laboratory; the goal of the lecture and laboratory is to contain the course to three hours each week.

Course Implementation

EG&CAD is taught using laptop computers. All freshmen at Rensselaer are required to have laptop computers. Students may purchase laptop computers from Rensselaer; these computers have all of the necessary software loaded on their hard drive. The software tools used in EG&CAD are commercial packages. Rensselaer's licensing agreement allows for these tools to be "imaged" onto the laptop computer so that students receive a fully functional computer when they come to campus. In addition to *SolidWorks*, the solid modeling program, EG&CAD requires *WebCT*, *PDM/Works*, and *RealAudio*. The usage of these tools in EG&CAD is described in the sections below. These tools are used in combination to provide a self-taught course using the laptop as the primary interface for all course materials and all course work[1].

WebCT for EG&CAD

WebCT is an Internet course management tool. The main features of WebCT are that it is secure (students must log in to the system), has two-way access between the instructor and the student, and provides students with course content and materials. In addition, WebCT tracks student usage of the materials so instructors can understand how students use the available web material. WebCT provides a number of different "rooms" that students can navigate through to obtain and submit materials.

Initially, WebCT was introduced in EG&CAD as a tool to deliver quizzes. A visualization quiz[8] was placed in WebCT and students were asked to try taking the quiz using the WebCT tool. The success of WebCT for the visualization quiz encouraged its further use in the course. After examining the capabilities of WebCT, the following list of additional material:

1. Lectures
2. Solid model parts, assemblies and drawings used in the lectures
3. Laboratory Assignments
4. All quizzes (described below in Evaluation Tools)
5. Weekly bulletins and general course information

Multimedia Lectures and Lecture Quizzes

All course lecture material is provided via streaming video files. These files were created during the summer of 2000 using Rensselaer's multimedia studio laboratory. Each 1-hour lecture was broken down into 4 or 5 10-15 minute segments and taped. Originally, the goal was to place the video lectures in WebCT. Due to bandwidth concerns, the lectures and the course manual were, instead, placed on 2 CDs. The CDs are bundled with the hand-sketching textbook. McGraw Hill (the text-book supplier) created the CDs for the course and packages them with the textbook.

Students are required to view the lecture segments prior to coming to laboratory. These CDs have been integrated into WebCT so that students may view them using WebCT or may view them outside of WebCT if they are not connected to the Rensselaer network.. The lecture segments do not need to be viewed together so students can view them as time allows.

Present Course Format in WebCT

In Figure 1, the present EG&CAD interface in WebCT is shown. The icons are arranged in the order in which they are expected to be used by the student. Most of the time, students will use the Weekly Lectures icon, the Quizzes icon, and the Weekly Assignments icon.

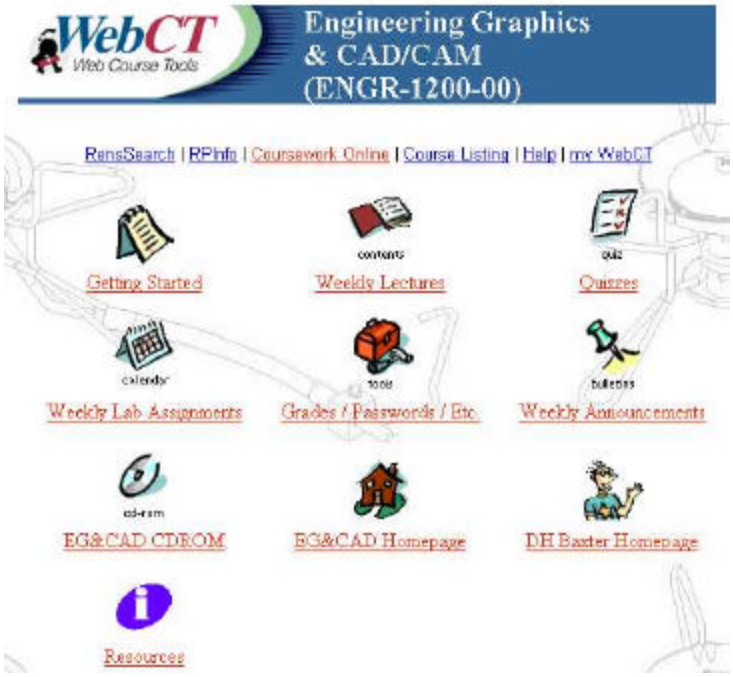

Figure 1: EG&CAD WebCT Cover Page

The Weekly Assignments icon leads to a calendar function with hyperlinks to the students EG&CAD schedule. The EG&CAD schedule is maintained on web pages created four years ago; these pages are publicly available at www.rpi.edu/locker/85/000685/public_html. It was felt that some public access to the

course should be kept. Some students live off campus and would have a difficult time accessing the data in WebCT due to Rensselaer's "firewall". The Quizzes icon leads students to their weekly quizzes and in class quizzes. These quizzes will be discussed shortly.

The Weekly Lectures icon leads students to a list of the relevant lecture material for each week. The Weekly Lectures page is shown in Figure 2.

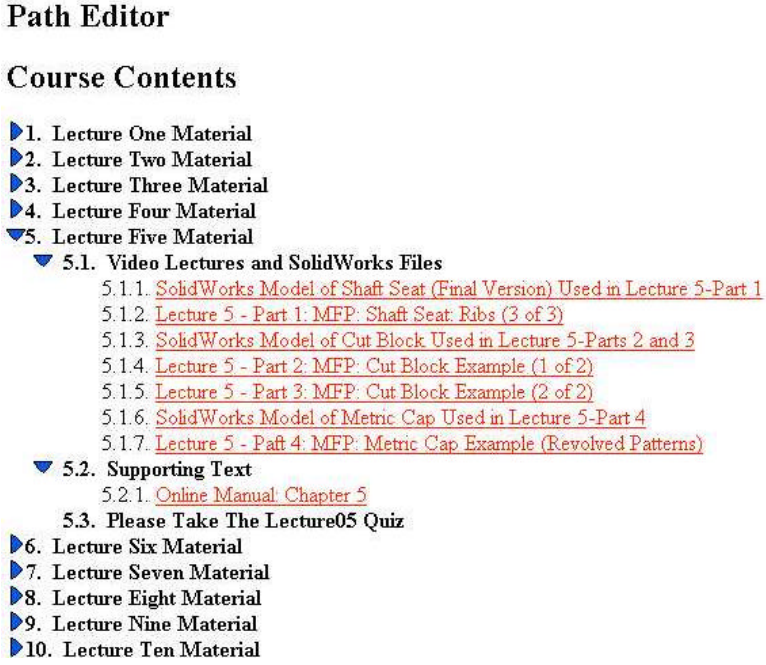

Figure 2: Weekly Lectures Main Page

The weekly material consists of the lectures and the supporting solid models (created in SolidWorks). The expected format is to load the SolidWorks material and then the lecture as shown in Figure 3.

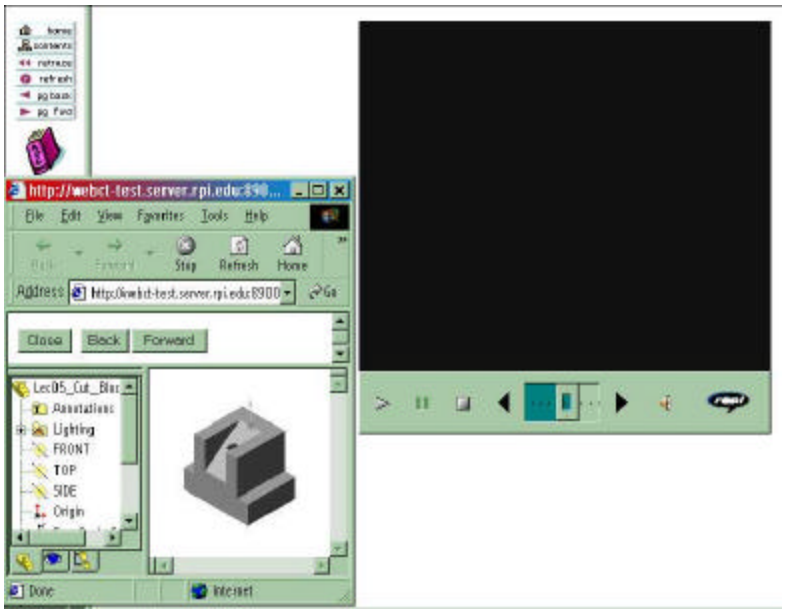

Figure 3: Video Lecture and Supporting Solid Model in WebCT

The SolidWorks model and the video lecture are loaded in WebCT in different windows. The Students can rotate and examine the solid model but can not make any permanent changes. The video lecture can be paused, rerun, etc as needed by the student. Many students are also running a session of SolidWorks so that they can build the model with the video lectures.

Students can click through the various segments with the control buttons in WebCT shown in the top left of Figure 3. If students choose not to use the WebCT interface, they can still access the SolidWorks models via PDM/Works. Room exists on the CDs to place the solid models with the lectures and online manuals; this may be done to better accommodate the off-campus students.

After running the lectures, students can load the online manual as shown in Figure 4.

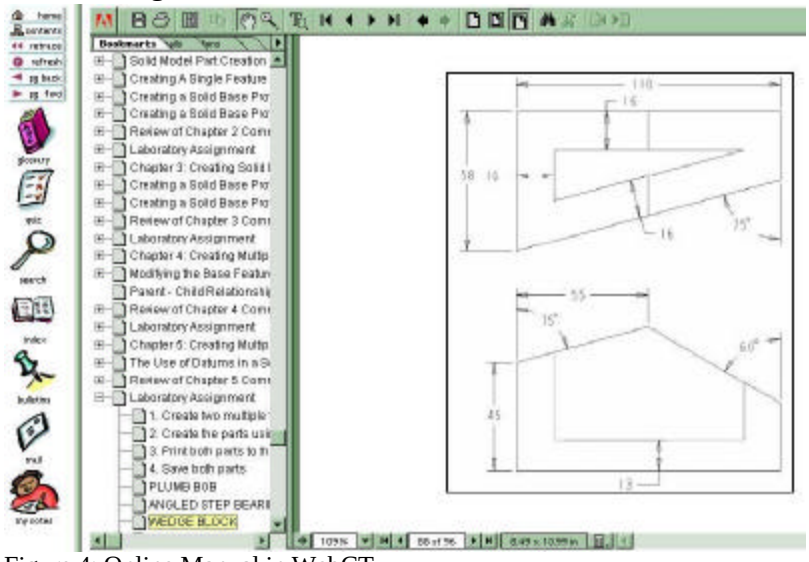

Figure 4: Online Manual in WebCT

After the student has viewed the material, they take an online quiz. The online quiz is given to ensure that the student has understood the material. Instructors can enter WebCT and determine who has taken the quiz and what scores were obtained. The student has three opportunities to earn a passing mark. An example of one test question is shown in Figure 5.

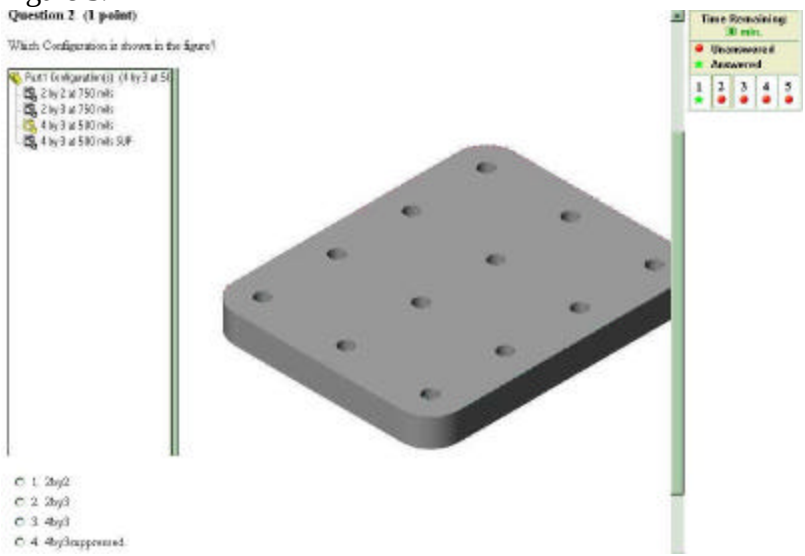

Figure 5: WebCT Online Quiz Question

Finally, the student can check to see what problems will be assigned in their laboratory session. Instructors are required to keep their web page syllabus sheet filled in with at least one week lead-time. This allows students to work ahead of the course schedule.

PDM/Works

PDM/Works is a database management tool that allows students to exchange data with their instructor. It is also used as a repository for common course data (such as the SolidWorks data that is used in the video lectures). Thus, if the WebCT server is not operational, students can still access all of the course lecture material. Another attractive feature of the software is the ability to store any type of computer file in the database. Several handouts have been created as either jpeg or pdf files; these files have been transferred into the database and no longer need to be emailed to students each week. A Grade sheets are also stored in the database manager and are hidden from all accounts save the instructor accounts. Likewise, the solutions to class problems are also kept in the database but are hidden from the students. An example of the PDM/Works interface is shown in Figure 6 where one part is active in SolidWorks, and the user is previewing a part from the database.

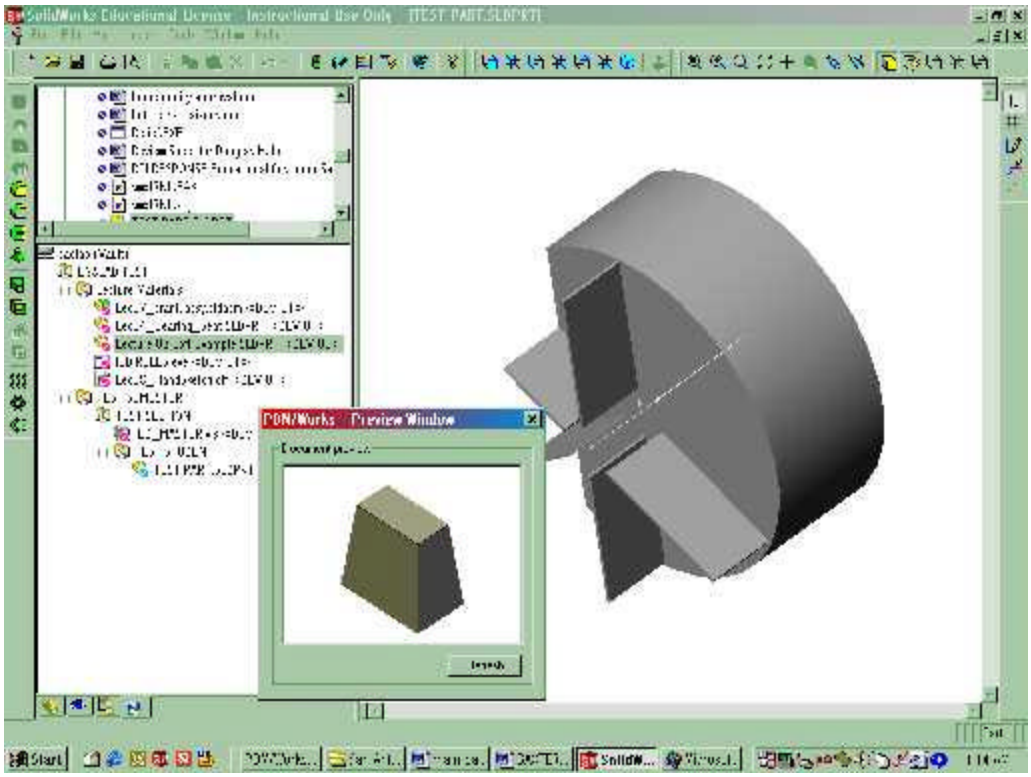

Figure 6: PDM/Works Interface

Database management has not been a formal study topic in EG&CAD. It is hoped that students will learn something about the use of database management from PDM/Works. From the limited usage of PDM/Works last semester, students seemed very pleased that they could submit data for grading in a secure system. They also liked how the instructor could read their data, make modifications or suggestions which would then be stored as a new data file. The two-way communication of the database allowed for students to seek help outside of class time. At present, PDM/Works has been implemented in EG&CAD and the sophomore design course, Introduction to Engineering Design (IED). Other design courses plan to start using PDM/Works in the coming semesters.

Evaluation

To help evaluate the effectiveness of the new course format, several techniques are used. To examine the effectiveness of the lectures, laboratory quizzes have been added in weeks 3, 6, 9, and 12. These quizzes are worth 5 points and consist of a small solid model or drawing that must be created by the student as a timed exercise during their laboratory session. The problems on the quizzes are similar to in class exercises. The major difference is students are not receive assistance from the teaching assistants while taking the quiz. Points are awarded for model accuracy and orientation (was the proper sketching plane selected etc.). Quiz scores averaged 4.2 for the first semester. Correlation between the quiz scores and final grades was performed and found to agree. The quizzes are administered through WebCT.

In addition to the four quizzes, a 50 question quiz[8] developed by Dr. Sheryl Sorby is used to determine overall course effectiveness. The test works with 2 and 3 dimensional visualization, measurement and technical drawing skills. In 1998, this test was introduced in EG&CAD as a paper test. In the Spring 1999 semester, the test was moved to WebCT. This quiz is administered through WebCT and is given at the beginning and end of the course. Final averages are examined between semesters and between the beginning and end of each semester. Rensselaer students typically average between 35-40 when they first take the quiz and average 70-75 at the end of the semester. While the final scores appear low, they are acceptable as the quiz examines topics not directly covered in class (using engineering scales and reading architecture drawings).

WebCT provides a variety of data with the quiz module. It provides a variety of quiz formats such as short answer, multiple choice and essay. Multiple questions can be added to a quiz so that WebCT can deliver a different quiz to each student. This technique is employed in the laboratory quizzes and the weekly lecture quizzes. WebCT is often able to grade the tests (the exception being essay or formulation problems). WebCT collects data for the test, and for each question in the test. In addition to total scores and distributions, data is collected on how students performed with each question. The statistical data for each question includes total of correct answers and total correct by test performance (that is, how the top 25% of scores did with the question, the bottom 25%, etc.). WebCT also tracks the number of times the quiz is taken (if multiple instances are allowed) and keeps statistics for each taking of the quiz. This data can be complied with the usage data from WebCT to determine if there is a correlation between the scores and the number of times students access the course materials. The data can easily be moved to spreadsheets for further examination. This data is generally not available to students although it is possible to release the data to the students if desired.

Traditional evaluation using opinion surveys continue to be used. Additional questions were included in the class survey. These questions dealt with the students' reaction to the video lectures and the use of WebCT. If this new course format is successful, it is supposed that the CAD work in the sophomore design course, IED, will improve. To examine this, several questions are being added to the IED opinion surveys. It should be noted that SolidWorks has just been introduced at Rensselaer; ProEngineer from PTC has been the solid modeling tool at Rensselaer and is still used by the non-freshman students. It is hoped that a baseline can be established with IED students this year and when the SolidWorks trained students take IED next year, comparative data can be taken. To further explore the students' reaction to EG&CAD, several focus groups facilitated by non-Rensselaer personal are planned for the Spring 2001 semester.

As this paper has been written during the Fall and Spring break, no formal data from the Fall 2000 opinion survey has been returned from the national testing center that compiles the data. All data is, regretfully, anecdotal. Several students have commented that they enjoy the course format and find it instructive. They like the ability to pause the lecture and try working the problems themselves. Most complaints have focused on two areas; the inability to get the software to run properly and the lack of a live instructor. Several comments from students indicate they expect a live lecture. Having the three teaching

assistants is not what they expected. It is hoped that the focus groups will be able to better draw out the students' concerns. The software issues are less course related as they concerned students interacting with Rensselaer's support structure. SolidWorks and Internet Explorer come installed on the freshman laptops; other students had to load SolidWorks from the RPI server. While most were successful, some students had difficulties.

An examination of the final grades and of the help sessions for the Fall 2000 semester has proven interesting. While one semester of data is inadequate, it is pleasing to note that the average for the final project improved from 30 (average of the last 4 semesters) to 34 (out of 40 points). Eighty one percent of the students received A and B grades. This matches the average maintained in EG&CAD for the past nine years. The failure rate in EG&CAD has always been low (2.2 students per 100 students) but was only 1 per 100 for the Fall 2000 semester. Accordingly, there was an increase in C grades with the number of D grades (3.1 students per 100 students) remaining the same. It should be noted that the number of students taking EG&CAD each year is 750-825.

A help session is offered on Sunday afternoons starting in the fourth week of the semester for students who need extra help. The fourth week was chosen as this is when multiple feature parts are introduced and some students begin having difficulties finishing their assignments. The number of students attending the help sessions is recorded. On average, 15 students will seek assistance during these sessions from weeks 4 to 11. After week 11, the number jumps to 30 with students working on their final projects. For the Fall 2000 semester, the weekly average before week 11 was 2 students, the final three weeks was 32 students.

Future Work

Continued evaluation is necessary to determine if the trends measured in final grades and requesting help exist. Further refinement of the lectures is planned for the summer of 2001. With the changes in the various software packages, it is vital to keep the video lectures current. Focus groups and additional questioning with the opinion surveys are planned for, at least, the Spring 2001 semester. If the number of students requiring assistance outside of class continues to drop, a plan is underway to evaluate using Microsoft's NetMeeting to allow students to interact with teaching assistants during specified "office hours". This would allow teaching assistants to monitor a computer and do other work if no assistance is required. This would also allow students to seek active help from anywhere on campus with an Ethernet connection.

Bibliography

1. Baxter, Douglas, and Lister, Brad, and Laplante, Bruce, "A New Model for a Self-Taught Solid Modeling Course", *Proceedings, American Society of Engineering Education: Engineering Graphics Division Mid Year Meeting*, San Antonio, Texas, January 2001.
2. Baxter, Douglas, "Expanding the Use of Solid Modeling Throughout the Engineering Curriculum", *Proceedings, American Society of Engineering Education: Annual Meeting*, St. Louis, Missouri, June, 2000.
3. Baxter, Douglas, and Bunk, Donald, *Engineering Graphics and Computer Aided Desig*n, Primus Custom Publishing, McGraw-Hill, New York, New York, 1999.
4. Baxter, Douglas, "Comparing Passive and Active Lectures for a Freshman Computer Aided Design Course," *Proceedings, American Society of Engineering Education: Engineering Design Graphics Divisio*n, Columbus, Ohio, January, 1999.
5. Baxter, Douglas, "Engineering Graphics and Computer Aided Design: A Foundation to Engineering Design and Analysis", *Proceedings, American Society of Engineering Education: Annual Meeting*, Seattle, Washington, June, 1998.
6. Bertoline, Gary, Wiebe, Eric, Miller, Craig, and Mohler, James, *Technical Graphics Communication, 2nd Editio*n, WCB McGraw Hill, Boston, Massachusetts, 1997.
7. Bunk, Donald and Baxter, Douglas "An Online Course In Solid Modeling", *Proceedings, American Society of Engineering Education: Regional Meetin*g, Union College, Schenectady, New York, September, 1995.
8. Sorby, Sheryl, Young, Michael "Assessment of a Visualization-Based Placement Exam for a Freshman Graphics Course", *Proceedings, American Society of Engineering Education: Annual Meeting*, Seattle, Washington, June, 1998.

DOUGLAS H. BAXTER

Douglas H. Baxter is the Director of CAD/CAM/CAE for the School of Engineering at Rensselaer Polytechnic Institute. He has been at RPI since 1993 teaching Engineering Graphics and Engineering Design. He is presently finishing his Doctorate in Mechanical Engineering. His research concerns integrating solid modeling tools with design methodologies to produce intelligent design tools.