

Evaluating Student Performance in a Freshman Graphics Course to Provide Early Intervention for Students with Visualization and/or Design Intent Difficulties

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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^[1]. With an increasing dependence on solid modeling skills required, it is imperative that the course content in EG&CAD be effectively delivered and absorbed.

Traditionally, when evaluating students in EG&CAD, the emphasis has been threefold: the creation of parts and assemblies in given orientations, the documentation of the parts and assemblies, and the use of engineering design intent in the parts and assemblies. The first two areas of evaluation were used when engineering graphics was taught on drawing boards. Maintaining these evaluation techniques has brought continuity to the ever expanding technology that has changed how engineering graphics is presented. The use of geometry orientation and documentation are not, however, sufficient to fully evaluate a student's performance as today's engineering design programs all for considerable modeling of the behavior of the geometry (be it part or assembly). Equations can link dimensions between sketches, parts and assemblies. Engineering drawing annotations can change with changes to the part they document; these important concepts (commonly referred to as the *design intent* of the model) must be taught as industry uses design intent to control changes in their product designs^{[2][3]}.

This paper will present how engineering students in the freshman graphics classes are evaluated in the three areas of visualization, documentation, and the application of fundamental engineering relations to solid models. When students create geometry in their introductory graphics course, the geometry and documentation is subjected to a series of tests by the instructors and teaching assistants to check both the correctness and

behavior of the geometry and documentation. It will be seen how laboratory assignment evaluations have been adjusted to examine specific skills and skill growth. In addition, continued evaluation of the laboratory assignments allows instructors to determine which students are having difficulty in a particular skill or concept; this allows for early intervention and correction targeted to these particular skills and concepts.

Motivation for Examination of the Grading Criteria

Evaluating student performance in a beginning course in Engineering Graphics must be done on several levels. Traditionally, the engineering drawing was the “finished product” of a graphics course and hence most of the evaluation concentrated on issues related to the engineering drawing. Typically, these items include:

1. Line Quality
2. Dimensioning Techniques
 - a. Placement
 - b. Validity
 - c. Tolerance
3. Folding Lines / Reference Plane
4. Scaling
5. Annotation
6. View Types
 - a. Principal Orthographic Views
 - b. Cross Sections
 - c. Detail Views
 - d. Broken Views
 - e. Auxiliary Views
 - f. Isometric Views

With the addition of solid modeling, the emphasis on the engineering drawing has changed. While still important, other aspects of the computer aided design (CAD) software warrant careful evaluation as well.^[2] These items include:

1. Modeling of Primitive Features
 - a. Part Decomposition into Single Features
2. Equation Modeling
 - a. Dimension Equations
 - b. Driving Design Equations
3. Relations Modeling
 - a. Relations between entities in a Part
 - b. Relations between entities in an Assembly
4. Part and Assembly Configurations
 - a. Part and Assembly Families
5. Surface Modeling
6. Assembly Modeling

The task for the modern graphics instructor is to balance the traditional evaluation items with the new solid modeling items to ensure the student is well rounded in their knowledge of modern computer aided design systems. The difficulty in determining the proper mix of old and new evaluation standards is well documented^[4].

In an attempt to strike a balance, the evaluation method discussed in this paper was developed. The work presented here comes from the evaluation of EG&CAD that was conducted after converting to a self-taught course^[5]. The evaluation method attempts to provide uniformity in grading in a multiple section course without sacrificing the individual instructors control over a section. The technique also provides students with very specific learning objectives for each laboratory assignment. To understand the context of the evaluation method, a brief overview of EG&CAD is presented.

Course Pedagogy

EG&CAD is a one credit course taught with a series of twelve one hour lectures over a fourteen week semester^{[6][7][8][9][10]}. 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^[11] 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 Implementation¹

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^[6].

¹ For an excellent discussion on using multimedia and other modern tools in a CAD course, see ^[3].

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The screenshot shows a web browser window displaying a video lecture. The browser's address bar shows the URL: `http://vcmr-66.server.rpi.edu:8000/SCRIPT/ENGR_1200_00/scripts/Internet Explorer`. The page title is "Engineering Graphics and CAD (Fall 2001 ENGR 1200_00) - WebCT 3.5 - Microsoft Internet Explorer". The video player shows a man in a red shirt speaking, with a CAD software interface in the background. The CAD interface displays a 2D drawing of a circle and a rectangle, with a mouse cursor visible. The browser's status bar at the bottom shows the page title "Weekly Lectures: Page 6/96" and the current time "2:45 PM".

Students can access their course syllabus within the EG&CAD web pages. As there are a variety of potential solid models available for each laboratory session, students from different sections often are asked to create different solid models. The EG&CAD schedule is maintained on web pages created in 1997; 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 secure spaces due to Rensselaer's "firewall". Thus students are able to view the lectures and (if they desire) work the laboratory session problems prior to their laboratory session.

SESSION	COMPUTER ASSIGNMENT 1	COMPUTER ASSIGNMENT 2	HANDSKETCH ASSIGNMENT AND QUIZZES	DATE
1	2D Cross Section Door Latch p. 36	2D Cross Section Corner Plate p. 40	START QUIZ	Thursday January 18
2	EXTRUSION Alignment Plate p. 57	REVOLUTION Bearing Cup p. 61	-	Thursday January 25
3	SWEEP Tire Clamp p. 71	LOFT Oblique Block p. 74	-	Thursday February 01
4	MULTI-FEATURE PART I Shaft Base p. 83	MULTI- FEATURE PART II Test Fixture p. 85	QUIZ (Lectures 1-3)	Thursday February 08
5	MULTI-FEATURE PART III Plumb Bob p. 90	MULTI- FEATURE PART IV Angled Step Bearing p. 91	-	Thursday February 15
6	FINAL PROJECT PART Spring		QUIZ (Lectures 4-6)	Thursday February 22
7	ASSEMBLY Torsonial Vibration Assembly p. 109	-	-	Thursday March 01

Figure 2: Portion of EG&CAD Syllabus as shown on Microsoft IE.

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. All course data including video lectures, SolidWorks data, and spreadsheets are stored in PDMWorks. This provides students with alternative means of accessing course data should they have a problem with their course CDs. In addition, data specific to the semester (such as final project handouts) are available in PDMWorks. PDMWorks was inserted into the EG&CAD tool set to provide students with the experience of using a database manager^[12]. One attractive feature of PDMWorks 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. By properly setting up the permission status of each account, sensitive data (such as the section datasheets) are only visible to the section instructors; students can not access these files even though they exist on the database. 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 3 where one part is active in SolidWorks, and the user is previewing a part from the database.

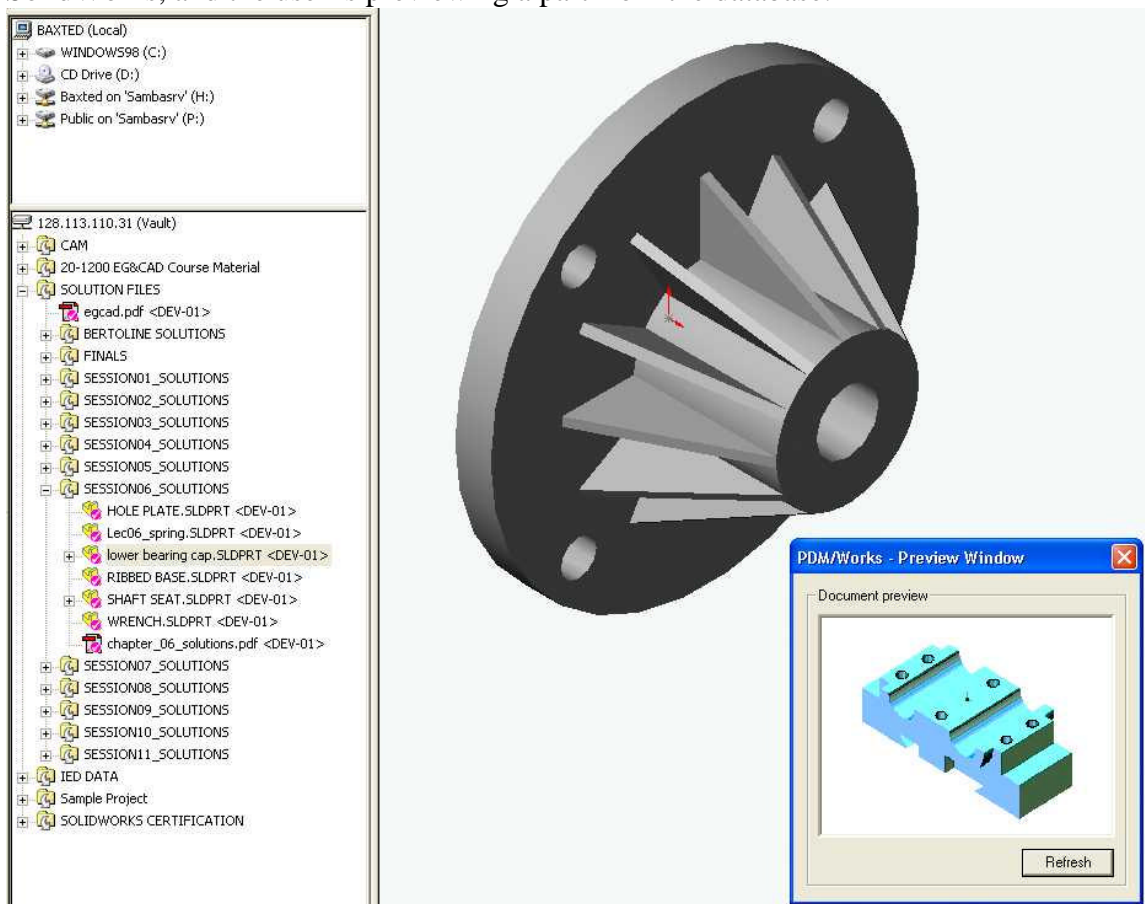


Figure 3: PDM/Works Interface

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 in the Spring 2001 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 fully 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.

New Grading Criteria

From the analysis of the course done after the Fall 2000 semester, it was decided to provide more uniformity in the grading of the laboratory assignments^[5]. Instructors and teaching assistants normally grade the laboratory assignments in class, providing suggestions to the students until the assignment is completed. Thus, if a student asks for help and submits the work during the laboratory, they will earn full marks (5 points). When students submit work late into the database manager, they receive a late penalty and additional penalties for incorrect work. The evaluation of the incorrect work was a cause of contention for students and their instructors (and teaching assistants). Many students only look at the geometry (for parts and assemblies) and assume that if the geometry “looks like” the problem in the book, they are finished. They ignore spatial orientation concerns and location of datum planes within the geometry or any geometry constraints. With engineering drawings, there was less ambiguity given the stringent rules of dimensioning and view layouts.

The goal of the new grading criteria is twofold. The first is to provide more stringent guide lines for grading the geometry problems. This would include evaluating design intent and engineering relations. The second goal is to provide both students and instructors with clear grading guidelines for each laboratory assignment. This includes both the geometry problems and the engineering drawing problems.

Every problem in the EG&CAD text book^[7] was examined and five grading criteria were developed for each problem. Each of the five grading criteria cover points made in lecture. In addition, at least one of the criteria is based on visualization, and one is based on engineering relations or design intent. An example geometry creation problem is shown in Figure 4.

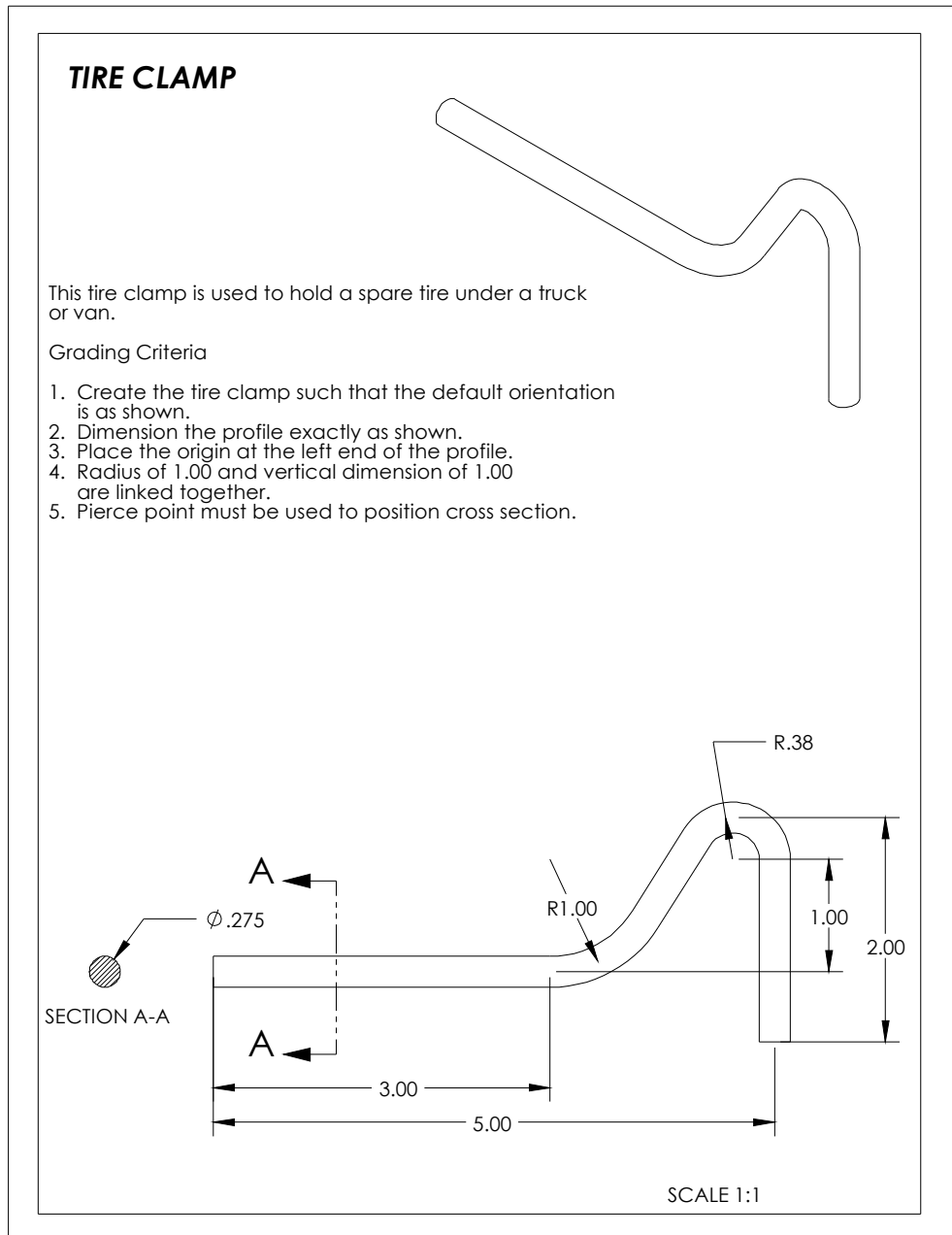


Figure 4: New Grading Criteria for Geometry Creation Problem^[7]

In Figure 4, the first grading criteria is the visualization criteria and the fourth grading criteria is the design intent criteria. This problem is from Session 03 and hence the problem is very simple and the grading criteria are very straight forward. Note how each of the grading criteria can be quickly examined by the instructor or teaching assistant and a grade of 0 or 1 for each criteria can be assigned. Again, during laboratory, students may ask questions and wait until the assignment is worth full marks before submitting. Having the criteria available as they do the assignment helps them to focus on the important aspects of the assignment. Furthermore, if the assignment is handed in late and incorrect, there is a clear grading guideline for point reduction.

As a second example, an engineering drawing problem is shown in Figure 5.

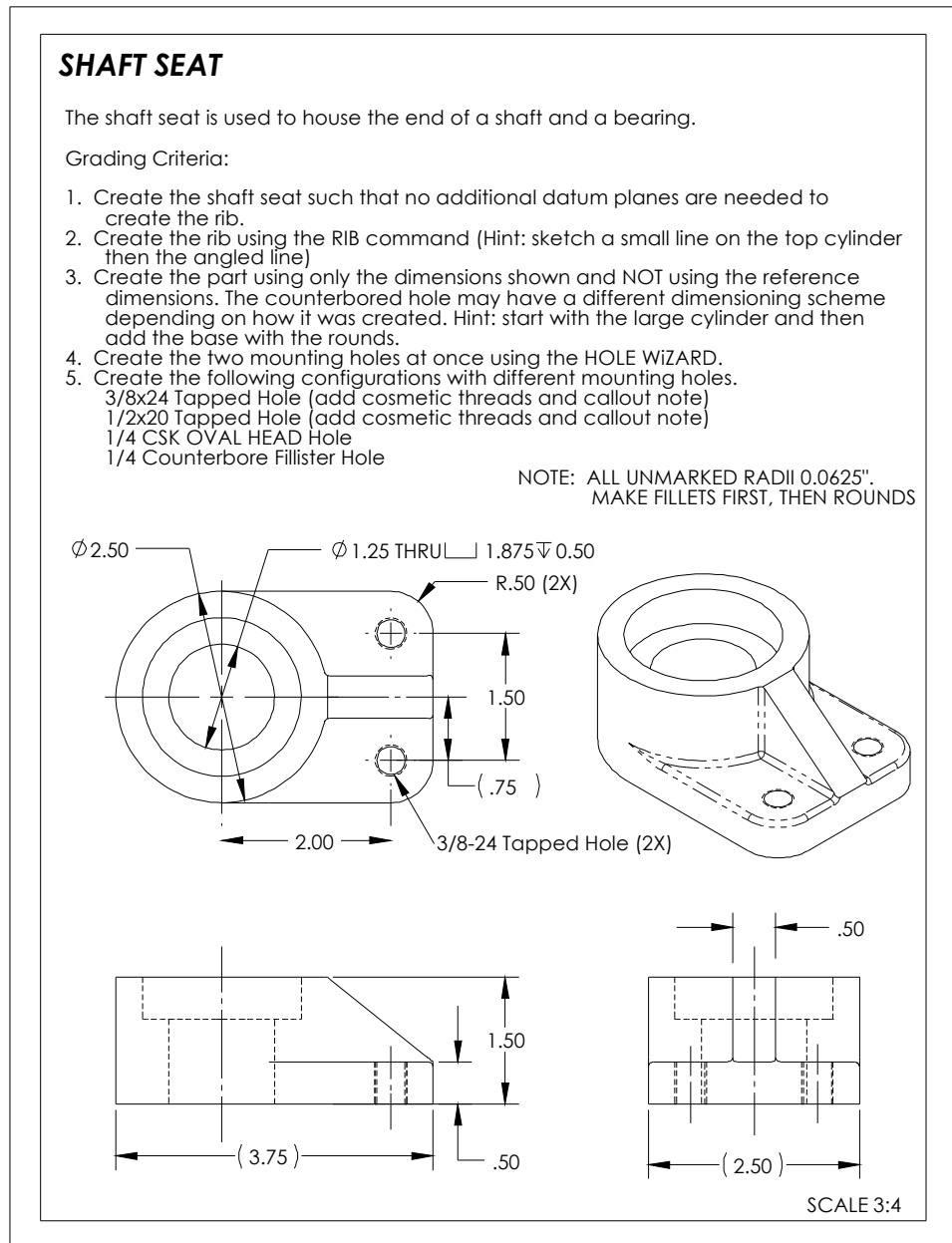


Figure 5: New Grading Criteria for Engineering Drawing Problem^[7]

In Figure 5, criteria 1 and criteria 3 cover design intent and criteria 2 and criteria 4 are feature driven. Again, as in Figure 4, the drawing can be quickly inspected and graded by the instructor or teaching assistants.

Evaluation

To help evaluate the effectiveness of the new grading criteria, several techniques are used. Some of these techniques are presented in the referenced papers^{[4][5]}. These

techniques include laboratory quizzes in sessions 3, 6, 9, and 12. The quizzes are similar to laboratory problems except they do 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 4.1 for the last 3 semesters. Correlation between the quiz scores and final grades was performed and found to agree. The quizzes are administered by the instructors and results are stored in PDMWorks. The final project is also evaluated. The final project scores follow a normal distribution centered between 73-78 points (out of 100) with a standard deviation of six points. This distribution has been constant since the implementations undertaken in 1999^[5].

In addition to the four quizzes, a 50 question quiz^[13] 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). Since the introduction of the new grading criteria, the scores for the diagnostic test have remained the same.

Initial Results

The course data from the Fall 2000 semester was analyzed and is presented here. Seventeen sections of EG&CAD were taught with a total of 387 students. Students were invited to comment (written) about the new grading criteria in the end of the semester opinion survey. Surprisingly, no negative comments about the new grading standards were reported. Fifteen positive comments were received; these comments noted that the new criteria allowed the student to “know” what their grade was prior to submitting their assignment. No change was noted in the diagnostic exam or in the final project. The latter result was not expected as it was felt that the focus on design intent would improve the final project grade (in the part creation portion of the grade). Instead, there was a slight decrease in the time students spent in creating the parts. Despite this slight increase, the complaint that the final project is too long was clearly indicated in the student opinion survey. The complaint about the time to complete the final project remains the most cited negative factor in the course.

The one significant change in the course was with the grade distribution. Over that last six years, the grade distribution of A's and B's has not varied significantly; 80% of the grades earned in EG&CAD were A or B. Changes have been noted with C's, D's, and F's^[5]. Specifically, the number of F's decreased with the new self-taught teaching mode for the course. The Fall 2000 semester marks the first real change in the numbers of A's and B's earned in EG&CAD. This is shown below in Figure 6 where the percentage of A's and B's dropped to 71%.

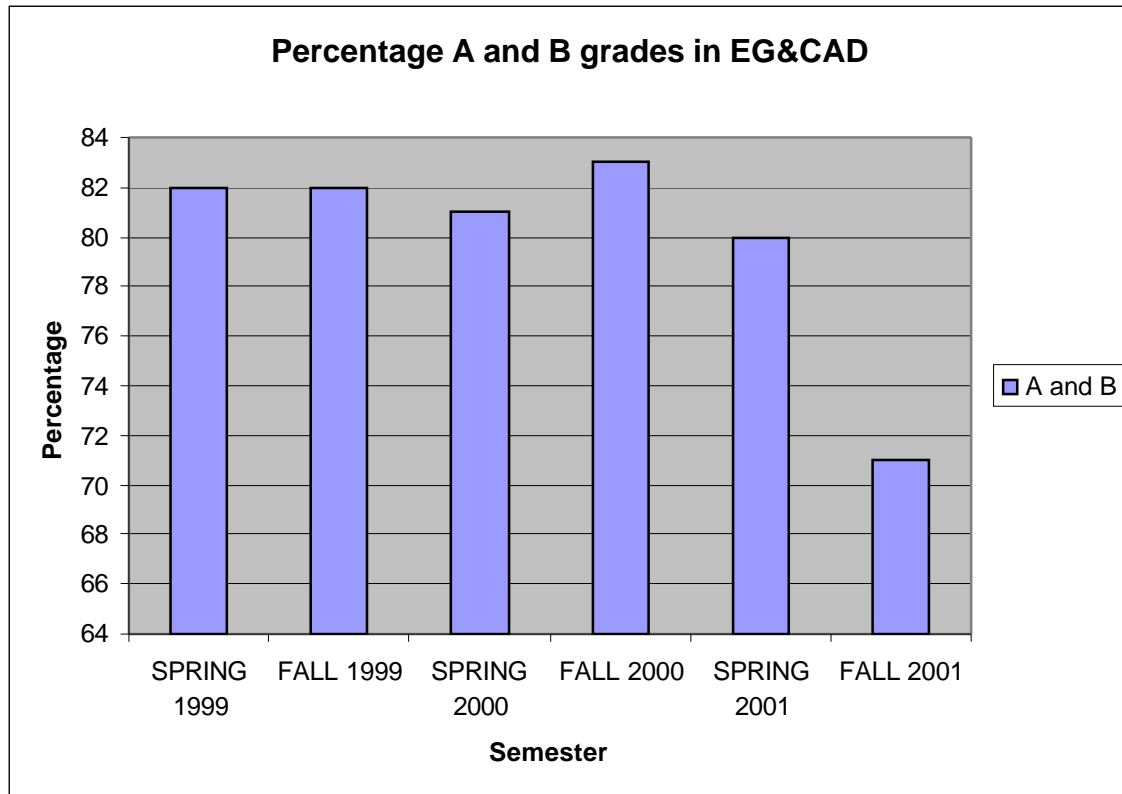


Figure 6: Percentage of A's and B's earned in EG&CAD for the past 6 semesters

The percentage of C grades rose 9% to create the largest number of C's ever earned in EG&CAD. In the past, students tended to either earn an A or a B, or fail. Further investigation found that the C students were students who continuously turned their laboratory assignments in late. This is not surprising given the present course structure. During laboratory sessions, students may have their work evaluated multiple times by the teaching staff until the assignment is correct; if the work is completed during laboratory; the laboratory marks should be perfect. Students who attend laboratory but do not finish are assigned a late penalty but they too are offered a chance to re-submit their work if it is not 100% (without incurring a further late penalty). Only students who fail to attend laboratory without a valid excuse must turn in their work without an opportunity for re-evaluation. Examination of the laboratory assignments showed that the rise in C's is mainly due to students skipping the laboratory session and then being unable to fully understand the grading criteria.

The EG&CAD teaching staff believes the grades from the Fall 2000 semester better reflect the students' performance than in semesters past. Clearly, there is increased standardization in grading between sections; a key concern with this large course. Furthermore, the larger distribution of grades indicates fairer treatment of the student base; it is now far more difficult to ignore a student who is habitually absent from class; an instructor must now ignore the time stamps in PDMWorks for that student and the instructor runs the risk of the course coordinator discovering the favoritism.

Future Work

Continued evaluation is necessary to determine if the trends measured in the final grades exist. Further refinement of the grading criteria will be conducted during the summer of 2002. Tracking of the visualization and design intent questions can be conducted from the data stored in PDMWorks. It is hoped that macros can be written that will scan the session spread sheets and inform instructors of students who continually turn work in late and miss key visualization or design intent criteria in several problems. As many instructors teach 3 to 4 sections each semester, they often find it difficult to carefully examine the spread sheets for failing students. An automatic detection system should aid in identifying students prior to their grade being placed in jeopardy with continued poor marks. Finally, with strict grading criteria, it is possible to have laboratory assignments automatically graded in PDMWorks via macros. The scores could then be fed into the correct spread sheet. This would allow instructors to spend more time with students in the laboratory and less time filling out spread sheets with scores. This work is expected to take about 1 year to program and bring to test in a limited number of sections.

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RealAudio is registered trademark of RealNetworks, Inc., Seattle, WA.
SolidWorks is registered trademark of SolidWorks Corporation, Concord, MA.
WebCT is a registered trademark of WebCT.com, Vancouver, BC.

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