

winter 2010
volume 74 number 1



THE ENGINEERING DESIGN GRAPHICS
Journal

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The online-only EDGJ is a reality as a result of support provided by East Carolina University; Biwu Yang, Research & Development, ECU Academic Outreach; Blake Smith, ECU Academic Outreach; and Cody Skidmore, an ECU graduate assistant and the Journal's Web Production Manager.

About the Journal

The Engineering Design Graphics Journal serves as the official journal of the American Society for Engineering Education, Engineering Design Graphics Division and provides a professional publication for educators and industry personnel associated with activities in engineering, technology, descriptive geometry, CAD, and any research related to visualization and design.

Manuscripts submitted for publication are subject to peer review by the EDG Journal editorial review board. The views and opinions expressed herein are those of authors and do not necessarily reflect the policy or the views of the EDGD.

Manuscript Submission

Please follow the guidelines provided on our website at <http://edgd.asee.org/journal/> APA Style is required.

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Print ISSN 0046-2012
Online ISSN 1949-9167


Message from the Editor



What's Next

By Robert A. Chin
East Carolina University

Now that the online-only Engineering Design Graphics Journal is a reality, what's next?




First, an ad-hoc Engineering Design Graphics Journal Advisory Board has been formed to provide the Journal with input from academic, business, government, and industry experts. Past editors of the Journal, who are still active with the Engineering Design Graphics Division, comprise the charter Board—Judy Birchman, Jon Duff, La Verne Abe Harris, Mary Sadowski, and Eric Wiebe. Jon Duff is serving as its chair. The Advisory Board functions in an advisory capacity and organizes and administers itself as it sees fit to fulfill its mission. Advice provided can range from the very esoteric to the very technical. The Board's suggested mission is to provide (1) the Journal with direction from those who deal with the subject matter published and (2) a voice for academia, business, government, and industry to ensure the direction of the Journal is in the best interests of the Journal and its readers. Key is ensuring we maintain a certain level of quality and make relevant incremental improvements. It is my belief that such an Advisory Board will help produce a better editorial product, which will benefit those it is intended to serve.

Second, our Associate Editor, Nancy Study, recently received an inquiry from an author on whether in effect the Journal is indexed by Thomson Reuter's Journal Citation Reports. It seems the author's concern was whether standard performance measures were available for the Journal. The matter of the Journal's performance has been the topic of numerous conversations. Nancy has suggested we consider having the Journal indexed by the likes of Thomson Reuter's Journal Citation Reports in order to take advantage of the

information available and to improve the visibility of the Journal. This will probably be a topic for the Engineering Design Graphics Division's Executive Committee to consider in June. If this is a matter of concern and is a priority to you, let us know.

Third, Cody Skidmore, an East Carolina University graduate assistant and the Journal's Web Production Manager, graduated this past December. He's now a staff member with The Fuqua School of Business, Duke University. Cody was instrumental in launching the online-only Engineering Design Graphics Journal. He is already sorely missed. However, he has agreed to continue assisting with the production of the Journal by assembling the various components that make up the Journal.

Finally, and we need your help with this; consider publishing the results of your research and other creative activities with us. The process is fairly straight forward. Prepare your manuscript electronically in accordance with the current edition of the Publication Manual of the American Psychological Association (the Manual)—see also <http://owl.english.purdue.edu/owl/resource/560/01/>. Then submit your manuscript, along with an abstract, figures, tables, and the like, as an attachment to Nancy Study, the Journal's Associate Editor at nstudy@vsu.edu. To ensure our articles are clear and consistent from article to article, issue to issue, and volume to volume, authors are asked to comply with the guidance provided by the Manual. The guidance addresses matters of the consistent use of punctuation and abbreviations, construction of tables, selection of headings, citation of references, table and figure titles, and quotations to name a few. In addition, the following must be considered

 **Message from the Editor** 

when preparing a manuscript for publication in the Engineering Design Graphics Journal: typeface and size, line-spacing, margins, order of manuscript pages, page number and page headers, corrections, paragraphs and indentations, use of uppercase and lowercase letters, headings, spacing and punctuation, seriation, quotations, and statistical and mathematical symbology. Guidance for preparation of the following is also provided by the Manual: title page; abstract; text; references; appendices; footnotes and notes; tables and table titles, notes, and rules; figures and figure captions; spell checking; and the cover letter.

Help the Journal's staff to improve the production of our flagship publication—the Engineering Design Graphics Journal.


Message from the Chair



“Awe and Pride”

Patrick E. Connolly
Purdue University

It is an interesting conundrum wherein we find ourselves in this educational world. We can focus on being outstanding educators and teachers, we can work in developing extensive research agendas and lengthy publication and presentation lists, or we can strive to develop partnerships with local, national, or even international industry partners to benefit our students and universities. All three options have relevance and importance in academia. However, is it possible to do all three at an effective level? What about two of the three? Must we focus on just one of the three areas to be truly exceptional? These are difficult questions that all of us have struggled with as we have endeavored to be our best selves. Sometimes it seems that recognition and reward for our efforts are minimal and slow in coming. Often it appears that efforts in the classroom or with industrial partners are not considered ‘as important’ as generating another conference presentation, journal article, or grant proposal. The pressure to publish in academia is widely accepted and much commented. The phrase ‘publish or perish’ is attributed to Cornell geneticist Kimball C. Atwood in 1950, and has been repeated an untold number of times over the intervening decades.

The purest purpose for publications, of course, is to contribute to the body of knowledge in our field, to make others aware of what we are doing, and to share ideas that may help others. However, what this ideal seems to have degenerated to for many is the incessant pressure to provide more research funding to continue the cyclical process that keeps universities running. What a shame that so many of us are frustrated and disillusioned with the publishing process!

As I think back to my early days in academia, I remember the awe and pride I felt with my first academic publication (in the Engineering Design Graphics Journal, naturally!). Over the years, I seem to have lost that feeling of accomplishment associated with succeeding at this process – it became drudgery, a task done grudgingly at best, and with open hostility and resentment at other times – again, what a shame! However, of late I seem to have found new motivation and joy in publishing, although I am not sure why. Perhaps it is because of the outstanding and enthusiastic graduate and undergraduate students that I have been able to coauthor with; maybe it is the great colleagues that provide an example of outstanding effort in all three areas mentioned above that has re-energized me; or it may just be that I have refocused myself on the ‘pure’ purposes for publishing listed above, instead of only focusing on tenure, promotion, and merit pay (all good things, too!). It is a wonderful feeling to enjoy learning new things and disseminating knowledge to others!

We are fortunate to have an excellent vehicle to help us in this process. Our Journal has a magnificent history of high-level scholarship, and serves an important role in our professional success. I hope we all will continue to take advantage of the opportunity to publish in the EDGJ. We are blessed with very dedicated and committed Division members that put in many hours of service that we may have this avenue for academic growth – let’s leverage this privilege and submit articles frequently to the Journal. If we will do so, we will all continue to benefit from the process, and certainly not ‘perish!’



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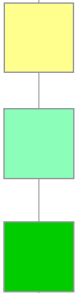
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North Carolina State University

Aaron C. Clark is an Associate Professor of Technology, Design and Engineering Education within the College of Education and is the Director of Graduate Programs for the Department of Mathematics, Science, and Technology Education. He received his B.S. and M.S. in Technology and earned his doctoral degree in Technology Education. Dr. Clark has worked in both industry and education, including administration at the regional college level. He lived and worked in Virginia, Tennessee and Maryland before coming to North Carolina. His teaching specialties are in visual theory, 3-D modeling, and technical animation. Research areas include graphics education and scientific/technical visualization. He presents and publishes in both technical/technology education and engineering. He has been and continues to be a Principle Investigator on a variety of grants related to visualization and education and has focused his research in areas related to STEM curricula integration. Dr. Clark has been a member of the Engineering Design Graphics Division of the American Society for Engineering Education (ASEE) since 1995; and has served in leadership roles and on committees for the Division since that time. He is also an active member of the K-12 Outreach Division within ASEE. Dr. Clark is recognized as a Distinguished Technology Educator by the International Technology Education Association.



Director of Membership

Kevin Devine

Illinois State University

Kevin Devine is an Assistant Professor in the Department of Technology at Illinois State University. Kevin has a Doctorate of Education degree in Curriculum and Instruction and Bachelor of Science and Master of Science degrees in Industrial Technology. Prior to becoming an educator, he was a Senior Engineer in CAD/CAM Systems and NC Systems in the aerospace industry. Kevin's teaching areas include engineering graphics and solid modeling, robotics technology and machining & CNC programming. Kevin's research interests include exploring ways of using modern engineering technology to teach STEM principles. Kevin received the 2008 Editor's Award from the EDGJ for an article describing his research using solid modeling software to help teach mathematics to high school students. In addition to being a member of ASEE/EDGD, Kevin serves on the Board of Directors for the Illinois Drafting Educators Association (IDEA).



2010 Election Results

**Director of Programs****Sheryl Sorby***Michigan Technological University*

Dr. Sheryl Sorby is a Professor of Mechanical Engineering-Engineering Mechanics and Director of Engineering Education and Innovation at Michigan Technological University. She recently served as a Program Director within the Division of Undergraduate Education at the National Science Foundation. Dr. Sorby received a Bachelor of Science in Civil Engineering in 1982, a Master's in Engineering Mechanics in 1985, and a PhD in Mechanical Engineering-Engineering Mechanics in 1991, all from Michigan Technological University. She was Michigan Tech's first graduate exchange student, attending the Federal Technical Institute in Zurich, Switzerland for the 1983-84 academic year. She has been on the faculty at Michigan Tech since 1986, starting first as an Instructor while completing her PhD degree and later joining the tenure-track ranks in 1991. Dr. Sorby is the former Associate Dean for Academic Programs in the College of Engineering and the former Department Chair of Engineering Fundamentals at Michigan Tech. Her research interests include graphics and visualization. She has been the principal investigator or co-principal investigator on more than \$5M in external funding, most from the National Science Foundation for educational projects. She was the recipient of the Betty Vetter research award through the Women in Engineering ProActive Network (WEPAN) for her work in improving the spatial skills and ultimately the success of women engineering students. She has also been a leader in developing first-year engineering and the Enterprise program at Michigan Tech and is the author of numerous publications and several textbooks. Dr. Sorby currently serves as an Associate Editor for ASEE's new online journal, *Advances in Engineering Education*. In 2007, she received the Distinguished Service Award from the Engineering Design Graphics Division of ASEE. She was the recipient of the Dow Outstanding New Faculty Award and the Distinguished Teaching award, both from the North Midwest Section of ASEE. Dr. Sorby is a member of the Michigan Tech Council of Alumnae. Her proudest achievement is the success of her three children. Her two daughters are pursuing graduate degrees in engineering and her son is still finding himself.

Online Working Drawing Review and Assessment

Jennifer McInnis, Alexandra Sobin, Nicholas Bertozzi
Daniel Webster College

Marie Planchard
Mass Bay Community College

Abstract

This paper describes the development and implementation of an online working drawing review video and online assessment tool. Particular attention was paid to dimensioning and ASME ANSI Y14 standards with the goal of improving the quality of the working drawings required in final design project reports. All members of freshmen design teams in the fall 2008 semester were required to watch this video and pass an online assessment before they could turn in their final design project reports. The School of Engineering maintained scanned copies of design project reports for the fall 2006 and 2007 semesters. A separate working drawing assessment rubric was developed and used to evaluate the working drawings for these semesters so that a comparison could be made with the project working drawings submitted for the fall 2008 semester. The working drawing review videos and the online assessment tool are available on request for Engineering Design Graphics (EDG) faculty members.

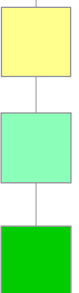
INTRODUCTION

Many first-semester freshman engineering design courses cover a wide range of topics such as the principles of the engineering design process, effective teamwork and project management, engineering graphics, three-dimensional solid modeling, oral and written presentations, an introduction to engineering analysis, and an introduction to specific engineering disciplines through industry tours and speakers. In addition, many include a Conceive-Design-Implement-Operate (CDIO) or similar type of project experience (CDIO Homepage, n.d.). It is difficult to fit all this content into a one-semester course. Often student teams do a good job with the analysis and fabrication of the physical prototypes of their projects; however, their final project reports are usually of lower quality. This seems to be especially true of their working drawings. The students have covered this material and have submitted related drawings assignments successfully earlier in the semester, so the challenge is to find ways to get them to review

this material on their own before turning in their reports without taking up additional class time. Could an online review and assessment tool be effective in addressing this problem?

Branoff and Totten (2006), in "Online Learning in Engineering Graphics Courses: Research, Tools, and Best Practices", had some interesting results with a 400-level 3-D CAD course. In spring 2004, students read the assignments, watched voiced-over slides streamed online, and took midterm and final exams. The following year, online quizzes were added for each reading assignment. The change in student performance between 2004 and 2005 was startling. The mean midterm exam score increased from 84 to 91 and the mean final exam score increased from 69 to 97, suggesting that following up online activity with immediate online assessment has a significant impact on effectiveness.

Branoff (2007) looked at the effectiveness of requiring students in an introductory graphics



course to take an online assessment of the week's reading assignment before coming to class for additional instruction. His analysis indicated that there was no relationship between student online assessment scores and homework or midterm exam scores. And yet on a post-assessment survey student responses were overwhelmingly positive regarding the value of online assessment helping them prepare for class and prepare for the midterm. They were also unanimous in their agreement that the faculty should continue to use the online assessment. The vast majority indicated that without the online assessment they would probably look at the chapters only when studying for exams. If the online assessment has the effect of getting the students to spend more time reading the book, then it seems worthwhile.

In addition to online assessment and voiced-over content presentations, some Engineering Design Graphics faculty members have begun supplementing their face-to-face student time with online voiced-over software demonstrations and sketching examples. Branoff and Wiebe (2008) used these techniques in a hybrid version of a foundations of graphics course. They ran three sections of the hybrid version and compared the final exam scores to the scores from fourteen face-to-face sections. They found that there was virtually no difference between the final exam scores in the hybrid and the standard face-to-face sections. Student surveys also showed that the students preferred the hybrid version over the face-to-face version by a margin of more than two to one. The results were so successful that in the spring 2009 semester they plan to offer only hybrid sections of this course along with a pilot for a completely online version.

The goal of the work described in this paper is to develop online presentations that can be used primarily to reinforce and review the material covered earlier in the course related to working drawings. Students will be required to pass an online assessment before they can turn in their final design project reports. This requirement will hopefully result in higher quality working drawings in their final reports.

ONLINE MATERIAL OVERVIEW

In the first semester design course at Daniel Webster College students are required to submit hand-sketches that cover a variety of topics as well as submit drawings of increasing levels of detail created in SolidWorks. After regular assignments have been completed in the first half of the semester, students then begin work on a CDIO design project. A large portion of the work for this project involves creating working and assembly drawings. In order to reinforce the principles covered in the assignments during the first half of the semester, a review module was added to supplement the in-class material.

Part of the difference between the drawing assignments completed early in the semester and the working drawings that students create for their projects is that the requirements for the regular drawing assignments are clearly specified, whereas for their design projects they must create their own solutions and make their own decisions in selecting and laying out working drawings. This difference of format seems to create a stumbling block for students, causing them to miss even some basic aspects of drawings. By adding this additional review material and assessment, students may be better prepared to apply the concepts they learned in assignments to the drawings they create for their projects.

The review module for drawings is organized into four topics: Basic Drawing Set-up, Baseline Dimensioning, Contour Dimensioning, and Assembly Drawings (Figure 1). A combination of videos, online assessments, and functional examples of each topic was used to cover and assess the proficiency of each student in the various areas related to drawings. Each topic begins with a diagnostic assessment, which is followed by review videos and presentations. The material for each topic remains available for student reference during later assignments and projects. Finally, a follow-up assessment becomes available if the student does not pass the diagnostic assessment (Figure 2).

Use of a course management tool like Angel (Angel Homepage, n.d.) allows the review mod-

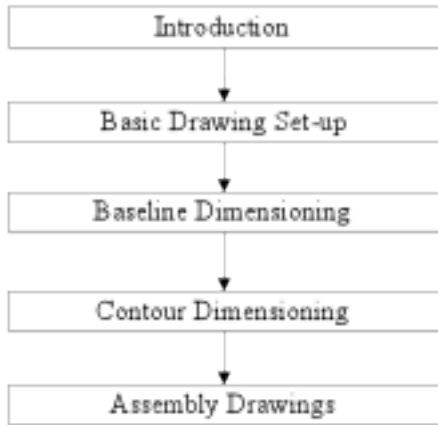


Figure 1. Flowchart of Review Module.

ule to be organized in such a way as to guide students through the material in a logical order. Students are introduced to the module with a video explaining the purpose, process, and topics to be covered. The first topic is then made available to the students, and they are only able to access the diagnostic assessment in that first topic. When the student submits the assessment, all review material becomes available. As the student passes the diagnostic, or passes the follow-up assessment, the next topic then becomes available (Figure 2). This sequence allows the online portion of the material to be organized in a similar fashion to face-to-face presentation of material.

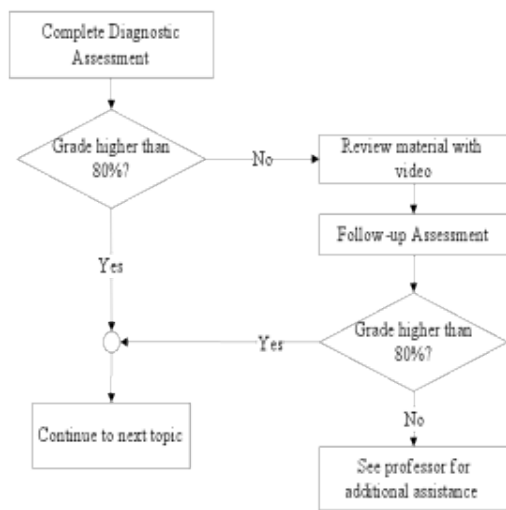


Figure 2. Organization of Individual Topics.

The purpose of the diagnostic assessment for each topic is to identify areas of proficiency for all students so they are not bored with information and additional assessments in areas in which they are already capable. The grade of the diagnostic exam will prompt instructions to the student to either move on to the next topic or complete re-view material. Students who are not proficient in a subject matter will be directed to view a short re-view video about the topic. After the review video has been watched, examples related to the topic and another assessment are made available, allowing the students to study and assess their understanding. If a student is unsuccessful in passing the follow-up assessment, he or she will be directed to seek help from the instructor of the course.

Assessments are composed of multiple choice, true/false, and matching questions. Both the diagnostic and follow-up assessments contain ten questions, and the diagnostic and follow-up assessments have different questions. The feature of reviewing assessment submissions is disabled so students can see their scores but cannot review their submissions. The assessments are also randomly arranged. There are no time limits on the assessments. These features encourage the student to take the time to consider the answers and to re-take the follow-up assessment when needed. Some questions from the Setting Up Drawings question bank are shown below (Figure 3).

2. Match the following:

A. Center Lines
B. Center Marks
C. Hidden Lines
D. Isometric View

- Dashed lines that are visible in front/right/top views to indicate edges behind the visible surface
- Dashed line that extends 1/8" past edge of feature that indicates a circular feature in the rectangular view
- Shaded, half scale view
- Cross with 1/8" lines that indicate a circular hole in the circular view

3. The isometric view should be shaded.

A) True

B) False

4. What are the standard three views normally imported into a drawing?

A) Front, Bottom, Left

B) Front, Top, Left

C) Front, Top, Right

D) Front, Bottom, Right

Figure 3. Setting Up Drawings Assessment Example.

Each topic in the review module focuses on a different aspect of working and assembly draw-

ings. Basic Drawing Set-up includes concepts such as first angle and third angle projection, hidden lines, center marks, center lines, scale, and general aesthetics of a drawing. Because they are a means of technical communication, drawings must be functional, but as graphics they should also be well arranged. As students proceed to Baseline Dimensioning, the functionality of the drawing is emphasized, covering reference points, when to use occasional chain dimensions to emphasize critical dimensions, and the best way to complete drawings for use in a machine shop (Figure 4).

Contour Dimensioning moves past 2-D parts such as plates to cover notches, arcs, and holes in great detail (Figure 5). In addition to a presentation outlining a number of rules that apply to contour dimensioning, examples are shown for a variety of contours to help students see the rules put to use. While holes are dimensioned in Baseline Dimensioning, greater emphasis is placed on understanding hole callouts in the Contour Dimensioning review material. Finally, students review the concepts of exploded views, and Bills of Materials in the Assembly Drawing review material.

Students continue through the material after passing an assessment for the first topic. Each new topic becomes available upon the completion of the previous material. All materials remain available for students who wish to revisit material at

later dates. Online course management programs like Angel facilitate this process of guiding students through material in an acceptable order while allowing them to complete the material outside of class on their own time. In this way material is accessible to students at all times, unlike presentations in class.

Material from the text book and examples of parts used in other assignments for the course are used in videos and materials for each topic since students are familiar with and have access to both. Videos highlight the main points of the topic, go through the process of preparing a drawing with emphasis in the main points of the topic, and conclude by summarizing the points. Both PowerPoint slides and SolidWorks examples are used in the videos to combine bulleted points, pictures of good and bad examples, and the actual process of creating the drawing to thoroughly cover each topic.

At the end of each topic, a brief summary of the points is available as well as an explanation of frequent mistakes on working drawings. These two summaries allow students to quickly refer to the main points without necessarily reviewing all of the details and examples associated with the topic. Students are encouraged to refer to this module when they start working on drawings for their design projects.

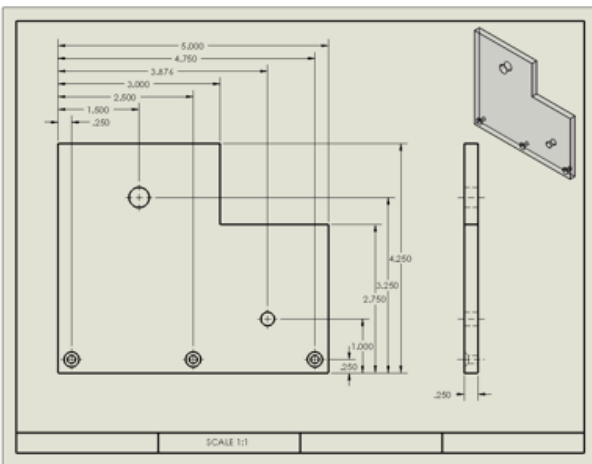


Figure 4. Baseline Dimensioning.

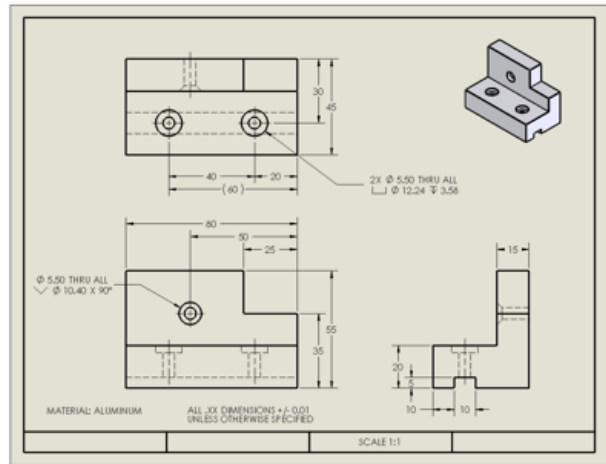


Figure 5. Example of Contour Dimensioning.

ASSESSMENT RUBRIC

The School of Engineering has maintained scanned copies of design project reports for the fall 2006 and 2007 semesters. The working drawing assessment rubric (Figure 6) shown below was used to evaluate the working drawings for these semesters so that a comparison could be made with the project working drawings submitted for the fall 2008 semester.

The following scale was used:

1. Incorrect in virtually all drawings
2. Incorrect in many drawings
3. Incorrect in only a few drawings
4. Correct in all drawings

RESULTS AND DISCUSSION

The data from the 2006 and 2007 design projects, which had no review material, were combined and compared to the data from 2008, which did. Seventeen groups from 2006 and 2007 (combined), and eleven groups from 2008 were scored. The averages of each attribute score are shown graphically in Figure 7. It can be seen that most of the attributes either improved or stayed approximately the same in 2008 from the previous two years. Statistical significance of the changes was not calculated due to the small sample size. Dramatic improvements were observed in Bill of Materials, Tolerances, and Shaded Isometric Views. These three attributes improved by about 1.5 points each. The exception to this trend is Thread Notes, for which the average score for 2008 was slightly lower than the previous two years.

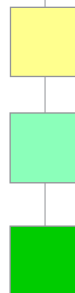
In addition to the averages, the distribution of scores within an attribute demonstrates the improvement seen in many attributes after the implementation of the review module. An example of this is Contour Dimensioning, the distribution of which is shown in Figure 8. While the average improved from around 2.5 to about 3.0, the distribution improved such that there were no teams

scoring 1, fewer teams by percentage scoring 2, and more teams by percentage scoring 3 and 4.

There were several factors that may have caused some attributes to stay relatively unchanged. This

Attribute	1	2	3	4
Line Weights				
Material Specified				
Thread Notes				
Hole Notes (Except Thread Notes)				
Tolerances Specified				
Dimensions Placed in Correct View According to Contour Dimensioning Principles				
Appropriate Scale and Placement of Views on Sheet				
Extension Line Offsets				
Lengths for Hidden Lines, Center Marks, and Center Lines				
Dimension Line Distance from Part				
Baseline Dimensioning				
Dimensions Lined Up and Grouped Logically				
No Superfluous Dimensions				
No Missing Dimensions				
Shaded Isometric				
Assembly is Exploded in a Logical Manner				
Exploded Assembly Trail Lines				
Exploded Assembly Balloon Placement				
Bill of Materials Complete Including Unit and Extended Weights and Costs along with Totals				
Upper Case Text of Appropriate Size Used in Title Blocks and BOMs				

Figure 6. Assessment Rubric.



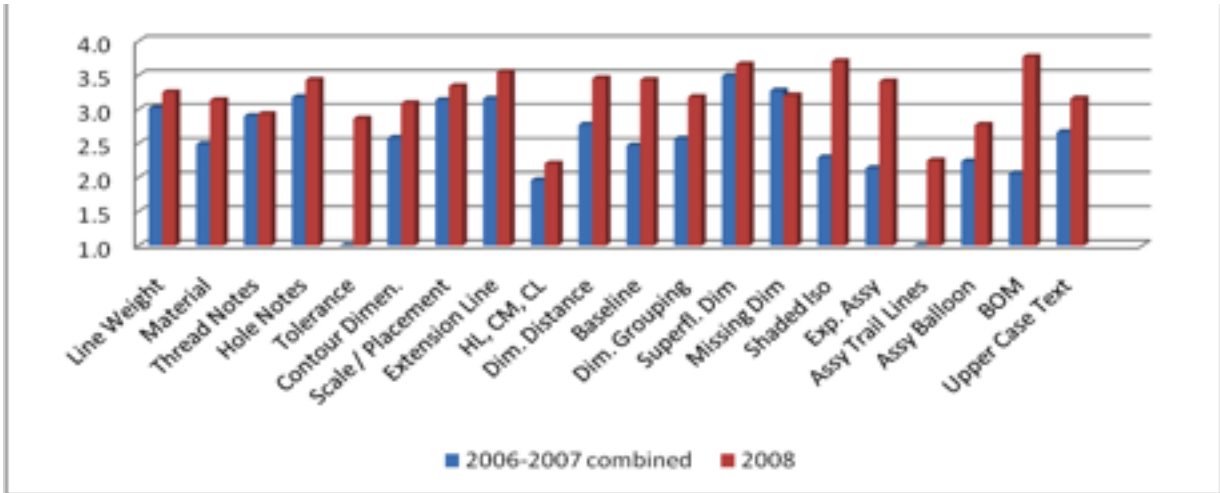


Figure 7. Attribute Averages.

was the initial usage of the module, and due to time constraints there was no opportunity to pilot test and revise the module before implementation in the fall 2008 semester. Second, it seems that some topics should receive greater emphasis in the review sections. Finally, some specific dimensioning concepts were not covered in the review module. While contour dimensioning was covered in detail, the examples may not have sufficiently covered the specific dimensioning related to the students' projects. For example, the technique for dimensioning keyways would benefit the students, since the final project uses keyways a number of times in the design.

In the future the module will be employed earlier in the semester, which may make it more effective. All teams are required to submit initial drafts of their working drawings for review, followed by a revised set of working drawings submitted with the final report. In fall 2008, the review module

was available before the final design reports were submitted but was not ready for student use before the drafts were due; if students complete the review module before creating their draft working drawings then it is likely that the draft quality will improve. Due to the end-of-semester crunch in fall 2008 it was likely that some teams did not have time to revise their working drawings between draft and final submissions. Requiring students to complete the module prior to submitting their initial drafts should make the review more beneficial.

CONCLUSIONS

Upon analysis of the data, it appears that the review module helped to improve the quality of working drawings submitted by freshman in their final report for Engineering Design I in a number of attributes. Contour Dimensioning, Baseline Dimensioning, and basic Drawing Setup seemed to be better than in previous years. However, the

improvement was not consistent across all the drawing attributes evaluated. It is likely that implementation earlier in the semester and more examples for the topics that didn't improve would help students create higher quality working drawings.

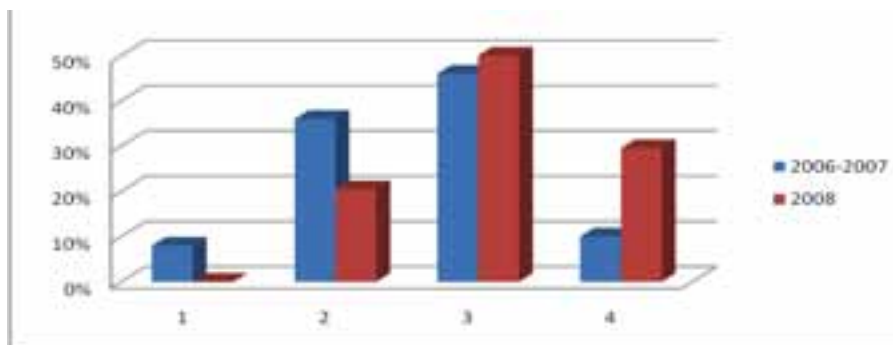


Figure 8. Distribution of Scores for Contour Dimensioning.

This module will continue to be used at Daniel Webster College and collaboration with other colleges should help improve its quality and provide data to further evaluate its effectiveness. Upon request, the review material and assessments will be made available to faculty interested in providing feedback or implementing the module.

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Using Pair Programming to Teach CAD Based Engineering Graphics

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Oral Roberts University

Abstract

Pair programming was introduced into a course in engineering graphics that emphasizes solid modeling using SolidWorks. In pair programming, two students work at a single computer, and periodically trade off roles as driver (hands on the keyboard and mouse) and navigator (discuss strategy and design issues). Pair programming was used in a design project, and in a subsequent year in a design project and several smaller special projects. Student outcomes for two years were compared with a previous year in which pair programming was not used. Improvements were seen in design project scores, overall course scores, and project submission rates. The course is normally taken by first year students during the spring semester. Retention into the sophomore year was also higher for students participating in pair programming.

INTRODUCTION

Pair programming, an ingredient in extreme programming, has been used extensively in software development in industry, and has been used experimentally in computer programming based courses for engineering students. This paper describes the introduction of pair programming into the course EGR 140 Engineering Graphics at Oral Roberts University. The course uses the CAD software SolidWorks, and emphasizes solid modeling. Pair programming was introduced in a design project and several smaller special projects.

In pair programming, two students work on the same computer, and share one keyboard and one mouse. One student is the driver, and is operating the keyboard and mouse. The driver is actually creating the solid models. The other student is the navigator, who is checking to see that the specifications in the assignment are being met, thinking about the next step, and giving advice.

Pair programming is a part of a larger soft-

ware development process known as Extreme Programming (XP), which has been reported to improve morale and customer satisfaction, and reduce project schedules (Williams & Upchurch, 2001). The components of XP can be used to detail an educational process to develop expertise in software design (Williams & Upchurch, 2001).

A number of studies have shown successful use of pair programming at the university level. A study involving 1200 students in introductory programming classes at two universities showed that students who engaged in pair programming performed as least as well as students working independently. A greater percentage of paired students passed the course with a grade of C or better. Also, a much larger percentage of the paired students declared a Computer Science major one year later (Williams, McDowell, Nagappan, Fernald, & Werner, 2003). In a study examining student behavior in computer labs, focus groups revealed that the paired students appreciated the ability to get quick answers to questions, without having to wait for an instructor. In addition, the lab instructors felt pair programming made their jobs easier as well (Williams et al., 2003). Stu-

dents using pair programming were more likely to turn in working programs, were more likely to turn in their assignments to begin with, and reported being more confident and more satisfied with their experience (Gehring, 2003). In another study of pair programming in an introductory C++ programming course, feedback from instructors indicated that students completed assignments in less time, and overcame roadblocks such as syntax errors more quickly. Student feedback also indicated that pair programming was an effective learning experience. Students also felt more confident, and that the quality of their work was better. Students felt the assignments were less stressful, and the instructors also observed a more positive and less stressful atmosphere in the class (Freeman, Jaeger & Brougham, 2003). In another study, students reported that pair programming helped them understand programming better, and regarded working with a partner as a positive experience (Howard, 2006-2007). In another study, student programming teams using pair programming produced the same amount of code as teams of students working individually. Students using pair programming reported finding errors more rapidly and produced more readable code (Bipp, Lepper, & Schmedding, 2008). In another study, pair programming increased student retention and program quality. A dramatic increase in the percentage of female students persisting in a Computer Science major after one year was seen (McDowell, Werner, Bullock, & Fernald, 2006). Combining cooperative learning techniques with pair programming, resulted in improved student performance, and students reported that pair programming was helpful to them in learning programming (Mentza, van der Walta, & Goosenb, 2008). In another study, 82% of students reported that pair programming was a positive experience, and 60% of students showed improved performance on exams after using pair programming (Šerbec, Kaučič, & Rugelj, 2008). When pair programming was used in an introductory computing class, the instructors observed that students engaged in higher level thinking more frequently, especially in extending class concepts to new applications (Williams, Wiebe, Yang, Ferzi, & Miller 2002).

Pair programming using an online virtual environment was studied. An increase in productivity, measured in lines of code divided by time spent was seen using pair programming. Students produced code with fewer defects, and scored higher on programming projects. Exam scores were not significantly affected by pair programming. The vast majority of students reported they preferred pair programming (Zacharis, 2009).

Pair programming has also been studied at the middle school level, especially for female students. Transcripts were used to assess interactions between middle school girls using pair programming to determine successful practices (Werner & Denning, 2009). Verbal responses from middle school girls involved in pair programming showed it was well received (Werner, Denner, & Bean, 2004).

Suggested guidelines for pair programming classes include pairing students by skill level, making lab sessions that use pairing mandatory, scheduling so assignments can be mostly finished in session time, and creating a collaborative environment (Bevan, Werner, & McDowell, 2002). Additional guidelines include using closed laboratory sessions, strict attendance policies, peer evaluations, instructor assigned pairs, training of teaching assistants and students, rotating pairs, and a rapid response to non-participating partners (Williams, 2007).

The use of pair programming in educational contexts has been reported primarily in introductory programming courses. Pair programming has also been used in a Computer Architecture course. Student feedback indicated this was a positive experience, and student performance was in line with or better than that of students who worked independently (Gehring, 2003). This paper describes the author's experience in extending pair programming beyond the traditional computer programming context, and employing it in an Engineering Graphics class. Student performance and retention before and after the introduction of pair programming are compared.



PAIR PROGRAMMING IN ENGINEERING GRAPHICS

This paper describes the introduction of pair programming into the course EGR 140 Engineering Graphics at Oral Roberts University. The course teaches the use of SolidWorks in creating solid models, assemblies, and drawings of those models. The approach is primarily learning by doing with small amounts of instruction, modeling and coaching. Pair programming was introduced through special design projects. The students worked individually on the majority of in-class work and homework assignments, as well as all tests. Thus students worked individually in acquiring basic skills, and worked in pairs when applying those skills to more challenging and open ended problems.

An example of the possible steps used to produce a SolidWorks model of the CD case lid shown in Figure 1 is given below. The use of the Mirror feature requires some planning ahead.

Steps:

1. Sketch and dimension a rectangle for the top of the lid, and extrude it into a solid object.

2. Sketch and dimension a rectangle for one side of the lid, and extrude it into a solid object.
3. Sketch and dimension a cut for the side of the lid to shape it and make the cut.
4. Sketch and dimension a rectangle for the slot in the side of the lid and make the cut.
5. Sketch and dimension a semicircle for the tabs on the side of the lid. Use the plane of the lower side of the slot. Extrude this sketch into a solid tab.
6. Use the Mirror feature to create a second slot and tab on the same side.
7. To make the ribbing on the side, sketch and dimension a small rectangle on the side. Create a pattern of these rectangles along the side. Cut indentations for the rectangles.
8. Use the Mirror feature to create the second side, with slots, tabs and ribs.
9. Set the material to acrylic.

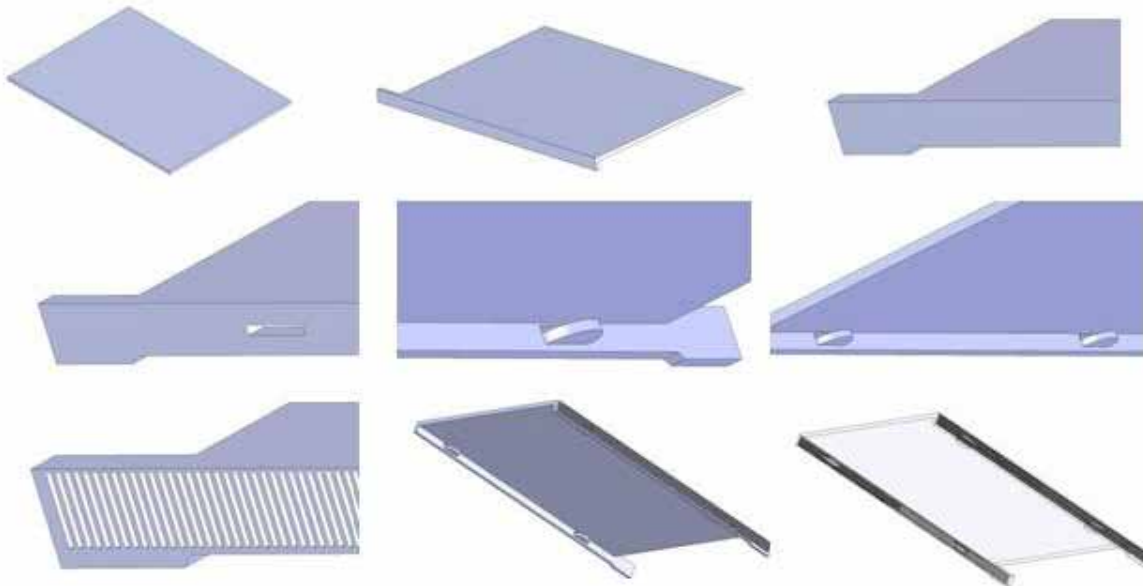


Figure 1. Process for creating a SolidWorks model of a CD case lid.

The solid modeling task is very different than writing a computer program, since a procedural object is not being produced and no new data structures must be designed. The solid modeling task shares aspects with programming, such as the need for conceptualization, identification of a process for creating a solid part, the limitations created by early design decisions, etc. Road-blocks in using the software due to student errors, similar to syntax errors, are also common and must be overcome. Significant differences in the tasks also exist. Rather than a sequence of instructions, a sequence of steps is identified to create the object. The creation of the objects and assemblies requires some common sense, planning and problem solving in selecting a process for creating the parts. In general, the product produced in solid modeling is less complex and more transparent than a computer program, so errors are easier to detect. Also, there is usually instant visual feedback telling the student if their steps to create an object are correct or not. However for more complex objects and assemblies, the constraints created by a design choice are not always immediately obvious. It is probably the novice status of the students that contributes the greatest challenges, so pair programming may be most useful for learning, but may not ultimately be part of their professional practice.

As in programming classes, the students represent a wide range of expertise. In this author's experience, some students can complete an exam in 10 minutes that some students will not manage to complete in 50 minutes. The idea of thinking ahead, planning, and making good initial design decisions is not innate to most students, and must be learned. Also, students working in pairs can be constrained to use a single computer, keyboard and mouse. In solid modeling, the mouse is used in a more 'analog' manner to create various shapes and approximate dimensions, while precise dimensions are entered using the keyboard.

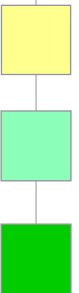
Although the students frequently do not interact in strict driver-navigator roles, this is the ideal presented. The students are to alternate roles. In

class, students alternate roles at fixed intervals of time. In industrial practice, this alternation frequently depends on which programmer is implementing their idea, and which is giving feedback.

Pair programming was introduced into an engineering graphics course normally taken by first year students in the spring semester. The course carries two credit hours, and meets for three hours per week. The students represent engineering majors, with concentrations in mechanical, electrical and computer engineering, biomedical engineering majors, and physics majors. A majority of the students are in the mechanical engineering concentration. A small number of students from computer science and other majors have also taken the course. The students typically have diverse backgrounds with respect to computer expertise, and intuition about solid objects, drawings and assemblies.

Pair programming was introduced in two consecutive years, 2007 and 2008. The first year, pair programming was limited to a single major project that was originally allotted four class periods. The second year, pair programming was used in the major project and several new smaller projects, which were allotted two class periods each. The remaining in class exercises and homework assignments, as well as all tests, were completed by the students working individually. In both years, all students participated in pair programming unless there were an odd number of students in the class. In this case, one student worked independently, and their performance is not included in the results below. This student might be repeating the class or frequently absent due to athletics, so working independently was more appropriate.

Pairs were selected by the instructor. Whenever possible, female students were paired together, and students were paired with other students of similar ability. The similar ability pairing was done in order to ensure participation by both students in the pair. While working in class, students were instructed to switch roles every 10 to 20 minutes. The times to switch were announced



by the instructor. There were some students who did not switch roles at these times, and there was one pair where only one student attended the class. The instructor was not able to monitor how the students interacted outside of class. For most of the smaller projects, which required one to two class periods, the students either completed the project during the scheduled class periods, or required a small amount of out of class time to complete it. For the design project, which was more involved, a significant amount of the work was performed in four to five class periods, although more out of class work was involved.

In 2006 and 2007, the major design project consisted of an assembly containing a shaft, flywheel, mount, baseplate and bearing that the students must create in SolidWorks. Some dimensions were specified, and others were required to be dependent on the specified dimensions. In 2008, the major design project was to create a model of a locomotive engine with working pistons that would drive the wheels based on photos and a diagram of the linkage between the wheels and pistons. In 2008, several smaller projects using pair programming were also assigned. In general these also required the students to model a solid object or assembly from a photo. The assignments are described in the appendix.

RESULTS

Several effects were noticed by the instructor when pair programming was introduced.

First, this introduced teams into the course, which made it more 'relational', which in general created a positive environment for first year students that should support retention. Secondly, the percentage of projects that were turned in on time increased. Third, the percentage of students who seemed 'lost' was reduced. Fourth, the instructor observed that students seemed to enjoy the class more and interacted more like professionals, staying focused on the project.

Students were considered to have not significantly participated in the class if they did not at-

tempt the final two exams and the design project. In general these students did not attempt other exams, turn in homework, or attend class. These students are excluded from the results for the design project and course scores and the retention study.

In spring 2006, prior to introducing pair programming, the average score on the major design project was 71.26 out of 100. Three out of 26 students did not turn in the project. Their scores (0) are not included in the average. After introducing pair programming, the average score increased to 86.2 in 2007 and 86.6 in 2008. In 2007 and 2008, all students who significantly participated in the course turned in the design project. It should be noted that the design project was the same for 2006 and 2007, and a more advanced design project was assigned in 2008. This data is summarized in Table 1.

Overall course scores for the students for 2006 – 2008 were comparable. After excluding students who did not significantly participate (one student in 2006, one student in 2007, and one student in 2008), the average over all scores were: 2006: 79.9, 2007: 84.81, 2008: 84.9. This data is shown in Table 1. Slight increases are seen in the years using pair programming, but the number of students is too small for these differences to be statistically significant. The comparability of results does indicate that pair programming was not hurting the students. This is consistent with other results for pair programming reported in the literature.

During the same period of time, retention improved dramatically. The list of students enrolled in EGR 140 in the spring semester was compared to the class roster for a mandatory departmental seminar in the following fall. Students who enrolled in the seminar and attended more than one seminar, or who otherwise were known to still be in the program, were considered to be retained. Students who were juniors and seniors in EGR 140, or who were retaking EGR 140, or who did not significantly participate in EGR 140 were excluded. Two students in spring 2006 who

Semester	Spring 2006	Spring 2007	Spring 2008
Total Students Considered	26	22	26
Average Design Project Score	71.3	86.2	86.6
Students Not Turning In Project	3	0	0
Overall Course Score	79.9	84.81	84.9

Table 1. Student Design Project Scores.

Semester	Spring 2006	Spring 2007	Spring 2008
Total Students Considered	23	21	25
Students Retained	13	19	19
Percent Retained	57%	90%	76%

Table 2. First to Second Year Retention of Students taking EGR 140.

were Computer Science majors were excluded. Transfer students in their first year at ORU were included in the retention study. The retention rates are indicated in Table 2.

Although the sample size is fairly small, this is a large increase in retention of students into the sophomore year, which is a key retention barrier. Although there may be other factors involved in the increased retention, it appears that the use of pair programming certainly did not hurt retention. Note that the students considered here are first year students participating in EGR 140, which is taught in the spring semester, rather than all students entering in the fall semester. Also the department offers a program in Engineering Physics, and a small number of students in EGR 140 are Physics majors, and these students are also included in the above results.

Although two sections of the course are taught every spring, comparison of these two sections would not provide a good basis for assessment, since one of the classes consists primarily of calculus ready first year students, and the other non-calculus ready students. Therefore the comparison is made between students taking the course before and after the introduction of pair programming.

CONCLUSION

Pair programming can be used in an Engineering Graphics course, and appears to positively in-

fluence student performance. In addition, higher levels of retention were seen after pair programming was introduced. The instructor intends to continue using pair programming in this course, and will attempt to improve student compliance in alternating roles.

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APPENDIX: DESIGN PROJECTS USED

Design project for spring 2006 and spring 2007: Develop a SolidWorks assembly for the pulley, shaft and mounting below.

Some dimensions are specified, other dimensions are dependent on these, and the wheel and shaft are free to rotate.

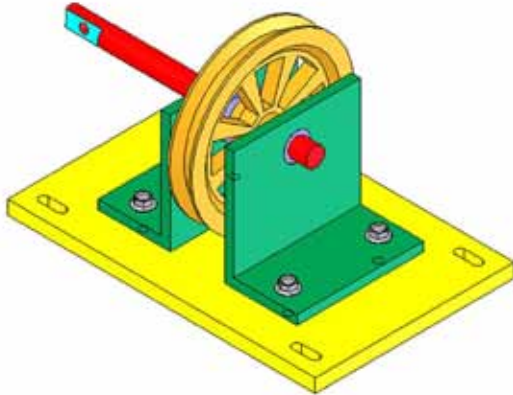


Figure 2. Assembly used for design project in spring 2006 and spring 2007. Courtesy of Dr. Richard Martin, PhD, PE, Aztec Engineering (R. Martin, personal communication, 2006).

Design project for spring 2008: Develop a SolidWorks assembly for a steam locomotive engine.

Partial instructions:

- You should ignore all of the detailed piping on the boiler.
- All bolts may be omitted.
- Clear glass (set material) window panes must be used on the cab. They do not have to slide or open.
- The drive mechanism should be included, except for the numbered items in the diagram (Figure 4) which may be omitted. Note that part of the drive mechanism is missing from the train in the picture.
- The headlight may be a simple circular shape on the front of the tank, and need not be clear. Extra credit will be given for more realistic headlights.
- Both pistons should be included, and the

lower one should work when the wheels are turned.

- The large wheels may be identical, and should all have spokes, like the first and third.
- The offset weights (crescents) on the large wheels may be identical for all three wheels, and similar to the rear wheel (flat on one side). They should be located opposite the connection of the wheel to the drive mechanism.
- The smokestack should have an opening at the top.

Other projects in spring 2008:

- Lid from a CD case. Students examine CD case lids and create 3D models.
- Mount for a dish antenna. Students create a 3D model of an antenna mount from a photograph.
- Can opener assembly. Students examine a hand operated can opener and create an assembly model.
- Electrical conduit box fabricated from sheet metal. Students examine conduit boxes and create 3D models.

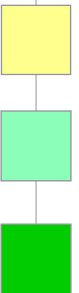




Figure 3. Locomotive photographs used in the Spring 2008 design project. Photographs by Paul Swanson, courtesy of Mid-Continent Railway Museum, North Freedom, Wisconsin (Swanson, nd).

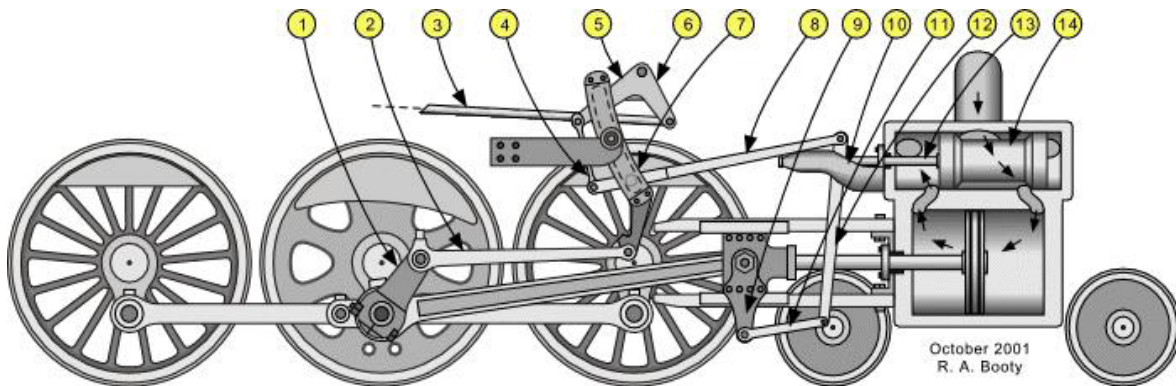
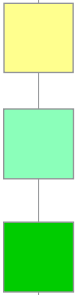


Figure 4. Locomotive drive mechanism used in the spring 2008 design project. Diagram is from Robert Booty's Steam Locomotive Valve Gear website: home.roadrunner.com/~trumpetb/loco/, used with permission (Booty, 2001).



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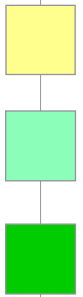
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Draft papers are due August 15, 2010.

Final papers are due August 31, 2010.

If you want your poster included in the conference proceedings, submit your poster by August 31, 2010.

All materials should be submitted to:
norma@mtu.edu

Travel grants are available for new and community college participants. See Schroff and Cengage Grants at <http://edgd.asee.org/awards/index.htm> for details.

