

2006-1051: DESIGN OF AN ENGINEERING GRAPHICS COURSE FOR A PRE-ENGINEERING PROGRAM

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Design of an engineering graphics course for a pre-engineering program

Abstract

A pre-engineering program is intended to give engineering students the core courses in engineering before transferring to a different university to finish their bachelor's degree. One course that usually is taught in pre-engineering programs is engineering graphics. The requirements for such a course are quite varied depending on the school and the engineering discipline to which the student transfers. This paper discusses the specific issues that arise in developing an engineering graphics course for a pre-engineering program. An outline of the course is presented including the material taught, homework assignment structure, timelines, design projects, and assessment of students' work. Instructor and student reactions to the newly designed course are discussed, including their views on the relevancy, work load, and overall reaction.

Introduction

The University of Wisconsin-Marathon County (UWMC) offers a two-year pre-engineering program. The purpose of this program is to give students the core engineering courses they need during the first two years in college. After completing the first two years, they transfer into one of many engineering programs at many universities. The curriculum of such a pre-engineering program must encompass necessary courses students need regardless of which specific major or university they transfer. Engineering graphics is one course which is required in many engineering programs. However, the topics covered in such a course are dependent on the specific engineering discipline. Due to enrollment and resources, pre-engineering programs typically can only offer one engineering graphics course to meet the requirements of all engineering majors. This paper details the development of an engineering graphics course for a pre-engineering program to meet the requirements of transfer universities regardless of the engineering discipline.

Most students at UWMC transfer to universities within the University of Wisconsin System. Because of this fact, the curriculum of the UWMC pre-engineering program is designed for smooth transfer to an engineering program within the UW System. The subject matter of most of the core engineering courses is well defined and consistent over time and across disciplines and universities (i.e. Statics, Dynamics, etc.). However, engineering graphics is highly dependent on current CAD technologies as well as current engineering practices in industry. Engineering graphics courses are constantly evolving and universities are including new and innovative topics based on current industry standards. These changes lead to new courses at universities and cause transferability issues with already existing courses in pre-engineering programs. Therefore, engineering graphics courses in pre-engineering programs need to change to meet the new requirements of the transfer schools.

At the University of Wisconsin-Marathon County, something very similar happened to what is described above. Engineering programs within the UW System changed their engineering graphics requirements and the engineering graphics course currently offered at UWMC no longer transferred. Therefore, the pre-engineering program at UWMC was required to create a new

engineering graphics course to ensure smooth transfer for students. Special attention was paid to make certain the new course met the requirements for each discipline at each transfer university. The idea was to create an engineering graphics course that would transfer independently of engineering discipline or university.

This paper will begin with a description of the pre-engineering program at the University of Wisconsin-Marathon County, including how it fits into the University of Wisconsin System. Next, the issues governing the creation and design on the new engineering graphics course is discussed. That is followed by an outline of the new course, including topics, scheduling, textbooks, and assignments. The implementation of the new course is then detailed including instructor and student reactions to the new course. Finally, conclusions will be made regarding the new engineering graphics course.

Pre-engineering program

To understand the pre-engineering program at the University of Wisconsin-Marathon County, the structure of the University of Wisconsin System must be grasped. The UW System is made up of 15 institutions. Two of the institutions (UW-Madison and UW-Milwaukee) grant bachelors, masters, and doctoral degrees. Eleven institutions (UW-Eau Claire, UW-Oshkosh, UW-Platteville, etc.) grant bachelors and masters degrees. One institution, UW-Extension, provides lifelong learning and access to university resources to all counties throughout the state. The final institution is the University of Wisconsin Colleges, of which UWMC is a part.

The UW Colleges provides the first two years of liberal arts general education to students. It is comprised of 13 campuses throughout the state, one of which is the University of Wisconsin-Marathon County. After receiving their first two years of liberal arts education, students transfer to a baccalaureate university to finish their bachelor's degree. The UW Colleges is accredited by the Higher Learning Commission; therefore, any credits earned will be accepted by other universities throughout the country. Also, if a student fulfills certain credit and GPA requirements while at the UW Colleges, they will be guaranteed admission to a UW System institution as juniors.

At an institutional level, the UW Colleges has 17 academic departments. These departments are institution-wide, meaning that members of each department are spread out among the 13 campuses. The academic department that manages the pre-engineering program is the Department of Computer Science, Engineering, Physics and Astronomy (CSEPA). Within the CSEPA department, there are four engineering faculty located at four of the 13 campuses. Distance education is used to reach engineering students at all 13 UW Colleges campuses.

The pre-engineering program at the UW Colleges is designed to give students the core engineering curriculum within their first two years of higher education. Aside from the calculus sequence and basic science courses, this curriculum consists of an introductory engineering course, engineering graphics, engineering economics, and the engineering mechanics sequence. This curriculum is designed to give students transferring to any engineering program at any university the core engineering education needed to succeed. Three institutions within the UW System grant bachelor's degrees in engineering (UW-Madison, UW-Milwaukee, and UW-Platteville). Since most students at the UW Colleges transfer within the UW System, the

program was specifically designed for transfer to engineering programs at one of these three universities.

Course development issues

This paper considers the development of a new engineering graphics course to fulfill the graphics requirement of each engineering major at each of the three UW institutions that grant engineering degrees. To ensure smooth transfers for students, the new graphics course needs to transfer directly as the required course for each major at each university. UW-Madison has different graphics courses, depending on the major program in which a student is enrolled. More specifically, mechanical engineering students take a different graphics course than civil engineering students. This problem exists at many universities as civil engineering students mainly work and draw in two-dimensions, whereas mechanical engineering students typically employ three-dimensional modeling. Due to enrollments and faculty resources, only one engineering graphics course can be offered at the UW Colleges, so this course must emphasize both 2D and 3D engineering graphics techniques.

Since two-dimensional drawing and three-dimensional modeling are both necessary for this course, deciding which computer aided design software should be utilized is another issue of concern. The UW Colleges has used AutoCAD as their CAD package in past engineering graphics courses. While this software is useful for 2D drawing, it is not very powerful for 3D solid modeling. A three-dimensional CAD package must also be utilized to teach the necessary solid modeling techniques required of most mechanical engineering programs. Since the other UW institutions use Autodesk Inventor, it will also be used as the 3D CAD package in this course at UWMC.

Other concerns regarding the structure of the course are how many credits it will be worth and how much time will the class meet each week. The transfer universities' engineering graphics courses vary from 2 to 3 credits. Their class meeting times range from 220 minutes per week to 250 minutes per week. Since this course must cover both 2D drawing and 3D modeling in detail, it was set at 3 credits and two 120-minute class meetings per week. Each class meeting will consist of 50 minutes of lecture on new material and 70 minutes of lab time to apply the newly learned subject matter.

Course design

With the framework of the new engineering graphics course determined, a more detailed outline of the course can be developed. This engineering graphics course must be designed to fulfill engineering graphics requirements for both civil engineering students and mechanical engineering students at several transfer universities. A list of topics was developed to encompass the engineering graphics fundamentals of each major. This course must cover the basic concepts of engineering graphics, including descriptive geometry elements and visualization. Also, the course must include projection theory, including orthographic views, pictorial representation, section views, and auxiliary views. Students must also be educated in dimensioning and tolerancing practices. In addition to the topics listed above, engineering drawing techniques must be applied to both 2D and 3D computer aided design software to satisfy the requirements of both mechanical engineering and civil engineering curricula.

As discussed earlier, both AutoCAD and Inventor will be employed as the 2D and 3D CAD packages, respectively. Students must not only apply the topics discussed above to these software packages, but they must also learn to apply these principles to hand sketching. While detail drawings are rarely done by hand anymore, hand sketching is still an important skill for engineers to convey graphical ideas quickly. This course must emphasize sketching to help students develop sufficient visualization and sketching skills.

This course can be broken up into three sections: basic engineering graphics concepts and sketching, 2D drawing using AutoCAD, and 3D modeling using Inventor. No one textbook was found that covered all of these topics, so three different textbooks were chosen to encompass all the material included in the course. Bertoline's *Introduction to Graphics Communications for Engineers*¹ was chosen to cover the basic engineering graphics concepts and hand sketching. This book is an excellent reference on projection theory, the layout of engineering drawings, dimensioning practices, engineering standards, and 2D drawing techniques. Shih's *AutoCAD 2006 Tutorial – First Level: 2D Fundamentals*² and *Parametric Modeling with Autodesk Inventor R10*³ were chosen to teach the basics of AutoCAD and Inventor, respectively. These books give a very clear, step-by-step description of the functions within the two CAD packages.

With the topics of the course outlined, attention must now be given to student workload and assessment. As discussed earlier, the class meets twice a week for 120 minutes each meeting. Fifty minutes is devoted to a lecture of new material and 70 minutes is scheduled for laboratory where students will practice the new concepts with the instructor present to help if necessary. A lab assignment is given each meeting to be turned in the following class period. These labs generally consist of a few problems, such as parts to draw. The labs are designed to be completed within the 70 minutes of lab time. The lab assignments account for 50% of the students' final grade.

In addition to the lab assignments, three projects are given for each of the three sections of the course detailed above. These projects are intended to bring a design component to the course, which is always desirable in engineering courses. These projects are also meant to focus on specific engineering disciplines, since the course must integrate with both mechanical engineering and civil engineering curricula. The first project is a sketching project where students must choose a physical system and describe how it works through hand sketches, using as little text as possible. This project assesses visualization, proportions, and projections. Also, since the students have a choice in what system to draw, the project can be either a mechanical engineering system (for example, a stapler) or a civil engineering system (for example, the structure of a building). The sketching project is worth 10% of their final grade. Next, an AutoCAD project is assigned where students must design the layout of a city park. They must create fully dimensioned detailed drawings of this park layout using AutoCAD. The focus of this project is to employ 2D drawing techniques in AutoCAD on a civil engineering design project. This AutoCAD project accounts for 15% of their grade. Finally, a project using Inventor is given where students must design a Lego assembly and create a complete set of working drawing for their design. This project is designed to use 3D modeling techniques used by mechanical engineers. This Inventor project is worth 25% of the students' final grade.

A course schedule was constructed using the developed topics list and chosen textbooks detailed above. This schedule uses the 120-minute (50-minute lecture and 70-minute lab) meetings,

Table 1: Engineering graphics course schedule

Concepts and Sketching		
Week 1	Introduction/Sketching/Proportions	Multiview Projections
Week 2	Perspective Projections	Section Views
Week 3	Auxiliary Views	Dimensioning/Tolerancing
Week 4	Working Drawings	Project Work Day
AutoCAD		
Week 5	AutoCAD Fundamentals	Basic Construction Tools
Week 6	Editing Tools	Object Properties
Week 7	Multiview Drawings	Basic Dimensioning
Week 8	Plotting	Auxiliary Views/Section Views
Week 9	Assemblies	Project Work Day
Inventor		
Week 10	Inventor Fundamentals	Solid Modeling Concepts
Week 11	Model History Tree	Parametric Constraints
Week 12	Geometric Construction Tools	Parent/Child Relationships
Week 13	Part Drawings	Auxiliary Views
Week 14	Section Views	Advanced Tools
Week 15	Assemblies	Project Work Day

twice a week structure discussed earlier. All topics must be covered within the 15-week semester at UWMC. The course schedule is outlined in Table 1. During the first four weeks of the semester, the course covers the basic concepts of engineering graphics, including projection theory, and dimensioning standards. These concepts are taught through hand sketching to give students the necessary practice to build strong engineering sketching skills. The next five weeks are spent on applying 2D drawing techniques in AutoCAD. The semester ends with six weeks covering the basics of 3D solid modeling in Autodesk Inventor. Notice that one work day is given for each of the three projects.

Implementation

Once the course was completely developed, implementation of the new course began with department and institution approval. The engineering faculty in the CSEPA department felt the new course was an improvement over the previous engineering graphics course offered at the UW Colleges. Also, they believed the new course better fills the requirements of the transfer universities within the UW System. The department was committed to implementing the new course pending approval of the curriculum committee of the UW Colleges. As expected, the institution approved the new course and it was implemented in the fall semester of 2005.

From the instructor's viewpoint, the new course was a success. The topics covered were well defined and encompassed material required for both mechanical and civil engineering curriculum. The course schedule allowed for smooth progression through the topics. No topic

felt too rushed, yet there was no difficulty covering all the subject matter. In the opinion of the instructor, the one area of improvement may be the project definitions. The concepts of the projects were reasonable, however, implementation of the projects revealed a few issues. One issue true of all the projects was the students could benefit from viewing an example project. An example can show the students more than the most descriptive text.

The description of the AutoCAD city park project was purposely vague to allow students design flexibility and also to reduce the desire of students to cheat. Unfortunately, vagueness leads to a wide range of student interpretations. Some students were very detailed and spent a great deal of time, while other students did very minimal work. While a range in students' work is expected, a more detailed and well-defined project should help reduce the large division in the quality of projects. A much more detailed and itemized assignment should be given. Room for creativity and design should still exist in the project; however, the description should give more guidance and detail of what exactly should be included in the design.

The Inventor Lego project was successful in that few students were confused about what was expected. However, some issues arose with the difficulty of the project and the large range in quality of students' work. As with the AutoCAD project, the open-ended Lego design project caused too much variation among students. Some students designed very elaborate structures with many complex pieces, whereas other students simply used square and rectangle blocks. While the range in student quality will always be there, an instructor should try to take steps to bring the lower quality work up to higher standards. This can be done by a better defined description of the project. Also, since most Lego pieces are simply minor variations of other Lego pieces, perhaps the project did not fully challenge the students to use a breadth of features in solid modeling. Before the next time the class is taught, more thought will be given to this project to ensure students apply most of the solid modeling techniques learned in the course.

Students generally felt the new engineering graphics course was fulfilling and useful. A short-answer survey was given to students at the end of the course to get their reactions to the new course. The survey asked students questions about the workload, scheduling, relevance, and overall impression of the course. In general, the students overall impression was that they liked the course and felt the topics were interesting. The students felt the workload was reasonable and the lecture/lab structure allowed for ample time to complete the assignments. For the most part, students felt most of their learning occurred during the labs and to a lesser extent the projects. Based on this information, the biweekly labs seem to be an important feature in the course, giving students time to learn the material with the instructor close at hand to help with any obstacles encountered in completing the assignment.

The one point where there was no consensus with the students was the pace of the course. Their feeling on pace seemed directly related to their previous experience with CAD. More and more high schools are offering CAD to students causing a large discrepancy in the knowledge base between students who have used CAD and those who have not. This difference in experience leads to a difference in the perception of pace of the course. One student who has experience with AutoCAD stated, "The pace was a little slow because I already had AutoCAD." Conversely, a student with no prior CAD experience said, "The course was pretty fast paced because each day we had a lab." This previous experience with CAD causes challenges in pacing the course so that students are neither bored nor overwhelmed. Based on the fact that the

student responses to the pace of the course were evenly dispersed, the tempo of the course seemed to be adequate as to not lose many students.

Another concern with teaching students that already know much of the subject matter is that they take no new knowledge away from the course. The challenge here is to make sure the course is based in engineering and not just learning CAD software. Students who know CAD need to learn to apply it to engineering concepts. Based on the survey results, students with previous CAD experience felt they learned new material and concepts in this course. One student said, “Even though I had already used both AutoCAD and Inventor prior to this course, I learned many new commands and tools to get the job done easier.” Based on the responses to the survey, students are gaining the material they need from this course, regardless of previous knowledge of the subject matter.

Determination of the transfer equivalencies at the three different transfer universities is an important step in implementing this new course. If the course doesn’t transfer as specific classes needed by the students, then the course must be altered as necessary to achieve a smooth transfer for students. Unfortunately, by the time of the draft paper submission deadline, no decision had been made by the transfer universities regarding transferability of this new course. However, it is expected this will not be a problem as the course was designed with transferability in mind. Hopefully, by the time of the presentation, a ruling will be made and the results can be presented.

Conclusions

A new course in engineering graphics was developed and implemented in to the curriculum of the two-year pre-engineering program at the University of Wisconsin-Marathon County. The new course needed to fulfill the graphics requirements of all engineering programs, specifically mechanical engineering and civil engineering, at the transfer universities. The new course is three credits and meets twice a week for 120 minutes each meeting during the 15-week semester. The course covers projection theory, hand sketching, engineering drawing using AutoCAD, and solid modeling using Autodesk Inventor. Both CAD packages are taught based on the need to fulfill both mechanical and civil engineering graphics requirements. Lab assignments are given each class period, as well as three semester projects: a sketching project on the functionality of some device, an AutoCAD project to design and lay out a city park, and an Inventor project to create working drawings of a Lego structure. These projects were designed to give students exposure to both mechanical and civil engineering projects. The new course was approved by the department and institution and implemented in the fall semester of 2005. The course was considered a success by both the instructor as well as the students. Changes may be made to the projects to make them more detailed and focused, as the current project descriptions resulted in vast interpretations by the students. The students felt the content, schedule, pace, and workload was acceptable. At the deadline of the draft paper, decision on transferability had not been made by the transfer universities; however there is no reason to believe the course will not transfer as expected.

Bibliography

1. Bertoline, Gary R., *Introduction to Graphics Communications for Engineers, Third Edition*, McGraw-Hill, 2006.
2. Shih, Randy, *AutoCAD 2006 Tutorial – First Level: 2D Fundamentals*, Schroff Development Corporation, 2005.
3. Shih, Randy, *Parametric Modeling with Autodesk Inventor R10*, Schroff Development Corporation, 2005.