AC 2007-67: PROJECT-BASED LEARNING IN A FRESHMAN COMPUTER GRAPHICS COURSE

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Abstract

This paper describes project-based learning in a freshman engineering course entitled, Engineering Graphics and Design at Loyola Marymount University. The major course requirement is to design and build a solid model of a real-world product. The course has been recently modernized to meet the challenges of conceptual design using graphics tools. The course introduces the students through a hands-on design projects. The engineering graphics topics include orthographic views, isometric projections, sectional views and dimensioning. Computer-Aided Drafting tools such as AutoCAD, Inventor and SolidWorks are introduced for both 2D and 3D. The CAD tools are also used for geometric analysis (Cosmos/M) and building solid models by rapid prototyping. The projects are conducted in student teams. The students utilize both written and verbal communication skills when they complete their projects. The work is written-up in a final report, and their results are given in an oral team presentation.

The goal of this paper is to describe and discuss the project-based learning in our freshman engineering graphics course. The evaluation of student learning will also be discussed. This paper will describe how projects and teams are selected, the team dynamics, project leadership and conflict resolution as they relate to each team. Several real-world projects such as design and prototyping of Boeing 737 aircraft, a functional flashlight will be described. This paper will also discuss the assessment tools for evaluating the team-based projects.

I Introduction

The future of nation’s university and industry is dependent upon the orderly, competent, selective and timely acquisition of high technology in the form of computer graphics, computer-aided design, testing and computer-aided manufacturing\(^1\). Not only must these individual capabilities be acquired, but they must be integrated to perform the complete process so that there is computer control of all facets from conception through the finished product. Although it is possible for many corporations to acquire their own CAD/CAM systems, it is still necessary for them to find a source of engineering talent proficient in the design, implementation and routine use of such an important resource. The primary source of these new high-tech professionals must come from the nation’s science and engineering colleges and universities.

Loyola Marymount University is a private, Catholic co-educational university with colleges of Liberal Arts, Communications and Fine Arts, Business Administration, Science and Engineering and a School of Law. The University has an enrollment of Approximately 6,500 students in all programs and offers undergraduate, professional and graduate degrees. An important goal of the University is to be of service to the entire Los Angeles community. Based on the needs of the large engineering, aerospace, manufacturing and computer industries in the Southern California area, the Mechanical Engineering Department offers a very strong program in Machine Design, Solid Mechanics, Metallurgy and Thermal Science. In keeping with this commitment to meet the educational needs of the surrounding industrial community, Loyola Marymount’s Mechanical
Engineering Department continually strives to upgrade its present curriculum and to be receptive to new areas of emphasis required in engineering education. Our department’s close contacts with industry pointed out the tremendous importance of a Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) program within the Mechanical Engineering curriculum.

Engineering Graphics and Design has long been recognized as one of the most critical core activities of the industrial product development process\(^2\). A number of evolutionary changes have taken place over the past couple of decades in the areas of graphics, design and manufacturing. Current methods in product development involve an integrated approach in which design, analysis and optimization, prototyping and testing are all integrated\(^3\).

This paper describes the project-based learning in the freshman engineering graphics and design course at LMU. The evaluation of the ABET criteria for the assessment of the student learning is also discussed.

### II Course Contents and Schedules

ENGR 140 (Engineering Graphics and Design) is a 3-unit course for the freshmen engineering students at LMU. The course is offered during the spring semester every year. The course consists of modules such as manual graphics, computer graphics using AutoCAD and SolidWorks, finite element analysis (FEA) and rapid prototyping. Each module starts with an overview of the process and a description of the hardware and software packages to be used. This is then followed by a more detailed discussion of the subjects using hands-on approach. The following Table 1 shows the topics and schedules of classes.

The concepts of integrated computer graphics and design are demonstrated using the following four modules of Manual Graphics, Solid Modeling, Finite Element Analysis, Rapid Prototyping.

1. **Manual Graphics**

While the main emphasis of the course is on the computer graphics, the first two weeks of the course are dedicated to manual graphics where students use free-hand sketching, orthographic projections, isometric drawing, sectional views and dimensioning. These topics help the students learn the visualization of objects in different views. These skills help them better understand computer graphics when they use computer to draw and generate views of objects.
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<thead>
<tr>
<th>Week</th>
<th>Modules</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weeks 1 and 2</td>
<td>Manual Graphics</td>
<td>• Freehand sketching</td>
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<tr>
<td></td>
<td></td>
<td>• Orthographic Projection</td>
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<td></td>
<td></td>
<td>• Isometric views</td>
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<td>• Sectional views</td>
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<td>• Dimensioning</td>
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<td>Weeks 3 and 4</td>
<td>Computer Graphics Using AutoCAD</td>
<td>• AutoCAD fundamentals</td>
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<td></td>
<td>(emphasis on 2D sketching)</td>
<td>• Object construction and editing tools</td>
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<td></td>
<td></td>
<td>• Object properties and organization</td>
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<td></td>
<td></td>
<td>• Basic dimensioning and notes</td>
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<td>Weeks 5, 6, 7, 8, and 9</td>
<td>Solid Modeling Using Solid Works</td>
<td>• 2D Sketching</td>
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<td></td>
<td></td>
<td>• 3D Solid modeling</td>
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<td></td>
<td></td>
<td>Assembly modeling and mating</td>
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<td>Weeks 10 and 11</td>
<td>Finite Element Analysis using Cosmos/M</td>
<td>• Principles of FEA</td>
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<td></td>
<td></td>
<td>• Analysis and design modeling</td>
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<td></td>
<td></td>
<td>• Static and dynamic analysis</td>
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<td>Weeks 12 and 13</td>
<td>Rapid Prototyping Principals and Application</td>
<td>• Principles and application</td>
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<td></td>
<td></td>
<td>• Steps of RP</td>
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<td></td>
<td></td>
<td>• RP of assembly models</td>
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<td></td>
<td></td>
<td>• Post processing and repair</td>
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<tr>
<td>Weeks 14, 15, and 16</td>
<td>Final Group Design Project</td>
<td>• Assembly design</td>
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<td></td>
<td></td>
<td>• Prototyping of models</td>
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<td>• Presentation of project</td>
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<td></td>
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<td>• Writing of final design report.</td>
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</tbody>
</table>

(2) **Computer Graphics Using AutoCAD and SolidWorks**

In this module, AutoCAD is used for 2 weeks to draw two-dimensional sketching of objects. AutoCAD is more important to civil engineering students who continue to use this software package for later use in surveying course. However, the main solid modeling software that is used in this course is SolidWorks. The advantage of using the SolidWorks is that it provides the parametric design and materials data that are used later for design analysis and prototyping of design projects. The design is parametric so that when the students change the dimension of a part or a feature, the entire design database is upgraded automatically. The advantages of solid modeling are the following:

- accurate description of model
- easier ways to find mistakes and solving problems because of improved analyzing tools.
- calculation and simulation.
- direct transmission of data to NC machines.
- quick changing of CAD models because of parametric design.

(3) Analysis and Optimization

In this module, the model created in the first phase, is analyzed to determine if it meets the design criteria. Most industries use Finite Element Analysis (FEA) to perform the analysis of product design. We use COSMOSXpress to complete the analysis because the SolidWorks software package comes bundled with Cosmos/M software. The advantages of analysis of the design are the following:

- verification of model meeting the design needs.
- ensures whether the model will stand up to the test of real environment.
- provides freedom to experiment with more than one variable.
- provides best design configuration (shape, size and topology).

(4) Rapid Prototyping

Rapid Prototyping (RP) is a new technology that is a part of the new methodology of integrated product development. RP takes information from the 3D CAD database and manufactures solid model (prototypes) of the design. One can turn a design concept into a prototype, test it for fit and forms, and even simulate product performance without excessive cost and time of traditional prototyping. The advantages of RP are the following:

- provides form, fit and functionality requirement.
- clear visualization of the model.
- early verification of any design error.
- prototypes can be used for casting or as a final models for many applications.
- reduce waste for the product development process.

The world has already entered into a new era of global competition for providing products and services. Rapid acceleration of new and emerging technologies is fueling this growth in all aspects of business. Companies engaged in product development and manufacturing are in tremendous competition to bring a product to market faster, cheaper, with both higher quality and functionality. Reducing the timeline for product development saves money in the overall time-to-market scenario. RP is the technology that helps companies reduce the cycle of product development and also facilitate making design improvements earlier in the process where changes are less expensive. The impact RP can have on product development is shown in Figure 1.
III Sample Design Projects

This section describes two of the several projects designed and prototyped by the students in the Engineering Graphics and Design class.

*Design of a Flashlight*

The Team Barcelona group of the class was assigned the task of utilizing the Autodesk Inventor 10 program to create schematics for a design project, which has to be eventually prototyped.

With the restraints and limited direction of the project in mind, the first step was brainstorming ideas, isolating the pros and cons of each design, and selecting a design, in this case, a flashlight. Then a rough sketch of the desired flashlight was made, showing as many details as possible. Figure 2 shows the preliminary sketch of the design. In addition, the team set out to make a functional flashlight in order to utilize problem solving skills that are encountered in actual engineering projects before prototyping. Rather than a random object which needs no constraints, the team knew that engineers are faced with hard constraints all the time, so the team should have more constraints than what was given.
Using a flashlight on hand, the team based many of the initial measurements off the initial flashlight. They then began to design the parts with rough sketches. After several drawings of each part, dimensions were set, and 3D design on Inventor began.

Several problems were encountered while using the program, each was handled and settled with simple tests, such as a trial-run on a part, or making sure that the circuit was complete in the battery holder. Analysis was held on the feasibility of making a prototype switch, but because of the unknown stresses and unknown strengths of the prototyping material, the team set against making a switch, and set to a prefabricated switch. Figures 3 and 4 show the drawing of the parts of the flashlight and the battery holder.
After examining this design, the team concluded that dimensioning is very important for the success of any design project, particularly one that stretches, and exceeds the rapid prototyping machine’s limitations on precision. They also determined that teamwork is the most important tool a group has when making a project, as often one person will catch something, and another person will miss it entirely. Figure 5 shows the conceptual design of the flashlight using the software and figure 6 shows the final prototyped product.

![Flashlight Conceptual Design](image1)

**Figure 5. Conceptual design from Inventor.**

![Flashlight Final Product](image2)

**Figure 6. Final prototyped product.**

The group would recommend several actions for the improvement of the project. First, more time should be spent on the optics of the reflector. Designing a better reflector would help the light coming from the flashlight appeared brighter and travel further. Another recommendation would be to spend more time dimensioning because everything must fit precisely in the end. In addition, we would make some parts of the flashlight out of metal if we had the option. This would save a lot of time trying to complete the connection of the negative charge.

**Design of Air Plane**

This team went well beyond what was expected of them in the course. The task they chose involved not only learning a software different from what was being taught, but also learning finite element analysis as part of the project. With one person already experienced with Solidworks, they decided to use the more powerful software than the Autodesk Inventor that was being taught. The team used some of the special powerful design tools of SolidWorks that were not available in the Inventor.

After several brainstorming sessions, the team decided to design and prototype a 737-700 aircraft. The thought was that it was a plane that they could be very exact on, as well as make it small enough for prototyping. They encountered many design problems as they took on this task, and still managed to do the job very well. Specifically, they found the difficulties with making the number of curves they had made. In addition, they found how the program slowed down significantly when presented with large and complex geometries.

As shown in Figure 7, the individual parts of the plane where made separately, and later assembled with small joints which fit snugly together. So snugly as the team found, that they spent hours sanding to make it fit because of error created by post-processing the material used to prototype the plane.
Figure 7. Parts of the plane in Solidworks

Figure 8. Finite element analysis of a section of the wing.

An additional feature the team felt important was to include a FEA analysis of the plane. They wanted to prove that theoretically the plane could fly if at full scale. The results they received was better than expected, as they calculated the theoretical lift, and found it would be sufficient to lift the full scale plane at 350 mph. Figure 8 shows the results of the finite element analysis.

The design expectations for the plane and the rapid prototype was very similar and the team was proud of the accomplishments. They were rather impressed because of the time and effort it required to make the curves work on the plane. As seen in Figure 9, the plane they were making had high expectations, and as seen in Figure 10 and by the enthusiasm of the team, the project came out exactly as they wanted it.
IV Evaluation of ABET Criteria

An ability to communicate effectively (Criteria g)

In the area of communication, the students were evaluated on the oral presentation given in class. They were graded on the project presentation, testing to see how well they were able to capture their audiences’ attention, the overall organization, whether or not they meet the course expectations, and the conclusion of their presentation. The performance of the student was assessed to be at the level of 3.52/4.0; which was scored using the Speech Evaluation in Table 2. Each student’s presentation showed not only a level of preparedness for professional presentation, but also an appreciation for the needs of communication when displaying their models.
Table 2: Speech Evaluation

Engineering Graphics and Design

Speech Evaluation

Objectives:
· Interesting, persuasive, creative – logical + emotional appeal
· Speak for 15 minutes

Rating Scale:
4 = Excellent (A) – Outstanding work
3 = Very good (B) – Exceeds standard, but not outstanding work
2 = Satisfactory (C) – Meets standard, but some improvement is necessary
1 = Unsatisfactory (D) – Below standard, needs drastic improvement

Rating Scale (20 Points Maximum)

· Opening (creative attention-getter) 4 3 2 1
· Organization (clear, logical) 4 3 2 1
· Preparation (well researched, rehearsed) 4 3 2 1
· Meets objectives (course expectations) 4 3 2 1
· Conclusion (climatic summary) 4 3 2 1

Total Points

An ability to design a system, component or process to meet desired needs (criteria c)

In the area of design, the students were evaluated on their final model and written report. They were asked to select a design project and submit a preliminary proposal to the instructor. During the selection process, the students went through the brainstorming process, discussed the feasibility of several projects before selection of a final project. Once the project was approved by the instructor, the students used their graphics, design and optimization techniques to design the component or the system. The average of the students’ performance was assessed to be at the level of 3.45/4.0; which was recorded in Table 3.

An ability to function on multidisciplinary teams (Conflict Resolution) (criteria d)

In the area of working in multidisciplinary teams, the students were evaluated on their effectiveness on conflict resolution. During the planning and design portion of the projects, several groups ran across conflicts pertaining to either group dynamics or conflicts with certain aspects of their individual design projects. Several of these groups consulted the instructor on possible solution to their conflicts. The instructor guided each group on the path to resolving their problems. Those groups who did not consult the instructor displayed a well understanding of conflict resolution either by looking at all views to the problems or balancing out each
opinion. An accurate assessment could not be obtained due to the nature of this assessment. Our assessment on how each group displayed an understanding of conflict resolution would be 3.5/4, due to our observations based on the written report, oral presentation, and personal observations of each group.

An ability to function on multidisciplinary teams (Leadership) (criteria d)

In the areas of leadership, students were evaluated on the overall group dynamics. During the planning and design portion of the projects, several groups operated under the leadership of one student who delegated all tasks and kept the flow of the group running smoothly, while the rest of the groups divided the leadership among each member and delegated equal tasks for each member. Though an accurate assessment could not be obtained due to the nature of this evaluation, our assessment on how each group displayed a leadership aspect of group dynamics would be 3.7/4, due to our observations based on the written report, oral presentation, and personal observations of each group.

Table 3: Project Evaluation

<table>
<thead>
<tr>
<th>Groups #</th>
<th>Project Name</th>
<th>Design and Written Report</th>
<th>Oral Presentation</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LMU Basketball Hoop</td>
<td>65.5</td>
<td>16.5</td>
<td>82</td>
</tr>
<tr>
<td>2</td>
<td>Excavator Model</td>
<td>72</td>
<td>19</td>
<td>91</td>
</tr>
<tr>
<td>3</td>
<td>Bike Model</td>
<td>64</td>
<td>18</td>
<td>82</td>
</tr>
<tr>
<td>4</td>
<td>LMU Airlines Model 747</td>
<td>77</td>
<td>18</td>
<td>95</td>
</tr>
<tr>
<td>5</td>
<td>AT-AT Model</td>
<td>72</td>
<td>18</td>
<td>90</td>
</tr>
<tr>
<td>6</td>
<td>Rotary Eggbeater</td>
<td>72.5</td>
<td>17.5</td>
<td>90</td>
</tr>
<tr>
<td>7</td>
<td>Rock 'Em Sock 'Em</td>
<td>65.5</td>
<td>16.5</td>
<td>82</td>
</tr>
<tr>
<td>8</td>
<td>The Roar</td>
<td>68</td>
<td>18</td>
<td>86</td>
</tr>
<tr>
<td>9</td>
<td>The Delorean</td>
<td>70</td>
<td>18</td>
<td>88</td>
</tr>
<tr>
<td>10</td>
<td>M1A1 Abrams Army Tank</td>
<td>68.5</td>
<td>18.5</td>
<td>87</td>
</tr>
<tr>
<td>11</td>
<td>Fire Fly</td>
<td>69</td>
<td>18</td>
<td>87</td>
</tr>
<tr>
<td>12</td>
<td>Rock 'Em Sock 'Em Robot</td>
<td>70</td>
<td>18</td>
<td>88</td>
</tr>
<tr>
<td>13</td>
<td>AT-ST Imperial Walker</td>
<td>70</td>
<td>18</td>
<td>88</td>
</tr>
<tr>
<td>14</td>
<td>Ford Snyper GT Hitman</td>
<td>65.5</td>
<td>13.5</td>
<td>79</td>
</tr>
<tr>
<td>15</td>
<td>JRRGN Rollercoaster</td>
<td>66</td>
<td>17</td>
<td>83</td>
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</table>
V Conclusions and Recommendations

This paper has described project-based learning in a freshman engineering course entitled, Engineering Graphics and Design at Loyola Marymount University. While the main graphics tools are introduced to students through manual graphics, computer graphics, analysis, rapid prototyping, the main thrust of the course is the project-based learning. The projects are conducted in student teams. The students utilize both written and oral communication skills when they complete their projects.

The paper has also described how projects and teams are selected, the team dynamics, project leadership and conflict resolution as they relate to each team. Several real-world projects such as design and prototyping of Boeing 737 aircraft and a functional flashlight have been described. The project has also discussed how the student projects were used to evaluate several important ABET evaluation criteria. Recently, the mechanical engineering department underwent ABET evaluation process and during the visit, the ABET evaluators were very impressed with the quality of the works of the students. Reactions from the students were very positive. All of them said that they enjoyed the course and learned a lot from the course.

Our recommendation is that, from now on, all computer graphics and design should involve the integrated methodology of solid modeling, analysis, rapid prototyping and testing.

Bibliography


