Learning CAD: Who is the Champion?

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Abstract

The final project in a Solid Modeling and Visualization course is aimed to enhance students' skills in creating 3D models by using different features of SolidWorks and following design rules and standards. Engineering students are assigned to form working groups to design chess sets for their final course project. The project grading rubric and allowable sizes for chess board and pieces are provided to students. All students need to actively participate in creating 3D models and in preparation of working drawing package. The best design will be selected by the vote of the course instructor and students and then it will be 3D printed and awarded to the winning team. The strongest chess players from each team will be invited to play against each other on the 3D printed chess set to earn extra points for their teams. Students will be evaluated by the effectiveness in using SolidWorks features, following design rules such as geometry dimensioning and tolerancing, preparing working drawing package, and performing both as an individual and as a member of a team.

Keywords

CAD; SolidWorks; Group design project; 3D printing; Chess set.

Introduction

Computer Aided Design (CAD) has a wide range of applications in everyday life and CAD courses are one of the main components of any engineering programs[1,2]. There are many studies that have analyzed the current reforms in teaching engineering graphics courses and the effects of development of 3D CAD technologies on mechanical drawing[3,4]. It has been consistent effort to introduce various teaching content and details to combine the handwork drawing with computer aided drawing[5]. In this regard, three aspects of CAD knowledge including theories of computer graphics, practice of CAD systems, and applications of CAD in mechanical design and manufacturing were discussed in many studies based on the requirements of engineering programs[6]. Several research has been undertaken on developing CAD curriculum to provide maximum value for students in their cad courses to prepare them for successful future careers. This was discussed in the context of considering different aspects of teaching CAD courses such as related mathematical foundation in CAD systems, required engineering knowledge and computer skills, design methodologies related to CAD systems, and ability of students to choose the most suitable CAD systems to meet their needs in conducting specific tasks[7]. It has been reported that students are aware of the importance of mastering commercial software packages that they would encounter in their future jobs which strengthen students' learning motivation and academic performance[8]. It has been shown that by using CAD systems in teaching engineering graphics course, a major improvement in three-dimensional thinking, solid modeling, creative ability, and the sense of engineering were observed in students[9].

Considering the importance of CAD in engineering education, this paper is focused upon the design and execution of the final project of the visualization and solid modeling course that has been taught in the Engineering School at Mercer University. The final project was designed to enhance skill set of engineering students in working with CAD systems, to improve their ability to combine theory and practice in developing products, and to help them to function effectively as a team.

Required Knowledge and Skills

It is of paramount importance that engineering students learn software packages which are commonly used in industries. SolidWorks is an efficient and easy to use design software which is widely being used in different companies and industries. The visualization and solid modeling course (2 credit hours) at Mercer University has been designed in a manner that students have exposure to both design theory and practice. They learn principles of engineering drawings in the lecture part (75 minutes per week) of the course. These principles include:

1. Orthographic projections
2. Dimensioning
3. Sectioning
4. Tolerances
5. Threads and fasteners
6. Assembly drawings
7. Pictorials

Engineering Graphics Essentials textbook from SDC Publications is required for this course. In conjunction with lectures, students learn how to use different features of SolidWorks in creating 3D models during lab sessions (3 hours per week). These features are listed here:

1. 2D sketches
2. Extrude, cut, mirror, and patterns
3. Revolves and sweeps
4. Fillets, lofts and drafts
5. Hole wizard, curve profiles and shell
6. Assemblies and assembly mates
7. Part drawings, dimensioning and tolerencing
8. Surfaces
9. Design tables
10. Assembly drawings and Bill of Materials (BOM)

The design concepts and 3D modeling skills that students learn during the lecture and lab sessions are essentials to prepare them to accomplish the final CAD project.

Project Description

The aim of the final design project is to enhance the ability of engineering students to fully integrate all acquired design skills and fundamentals. This project takes about 5 to 6 weeks to complete and will assist students in understanding how modern detailed designs are being developed. The first step is creating conceptual hand sketch, followed by developing solid models of the parts/assembly, and finally generating detailed manufacturing prints and assembly drawings. A short PowerPoint presentation on 3D models due at the deadline and all team members must contribute in the presentation. The submission of documents is due at the same day by midnight. All students need to actively participate in creating 3D models and in preparation of working drawing package. Each group must consist of maximum of 4 or minimum of 3 students. 3D models, hand sketch, working drawing package (PDF format), and written report will be submitted electronically on Canvas. The written report must be an individual work in which students should primarily report on the parts that they were responsible to design.

The allowable sizes for the chess pieces and board are: The king's height is 2 inches, the base (diameter/size) of the king is less than or equal to 1 inch and the chess board square is 1.25 inches. The height and the base size of all the other pieces are smaller or the same as the king.

Project Grading Rubric

The project grading rubric was handed to students around the middle of the semester. Different components of the rubric and descriptions of tasks associated with each component are given in Table 1. The final project is worth 20% of the course grade.

Table 1: Final project grading rubric

Project Components	Grade Percentage
Hand sketch: • Does it represent the chess set that was designed in SolidWorks? • Are any critical dimensions identified on the sketch?	10 %
Working Drawing Package: • Does the document meet ANSI standards? • Are all necessary dimensions given in the detailed drawings? • Are all tolerances specified in the drawings? • Are the assembly drawing and bill of materials included in the final document? • Is a standard parts sheet included in the document (if applicable)?	40 %
Written Report: • Does the written report explain the contribution of student in the final project?	10 %

Presentation & 3D Models: • Are all sketches in 3D models fully defined? • Do the 3D models properly represent the chess set? • Are final 3D models suitable for 3D printing? • Do students explain the importance of dimensions and tolerances in the design of the chess set?	40 %

Project Outcome

Chess sets with different styles and themes were designed by students as illustrated in Figure 1. Each design was evaluated by students from other teams during the PowerPoint presentation. The average scores from peer evaluation, and final scores by the instructor (on group work) for different chess styles are given in Table 2.

Table 2: Scores on Projects

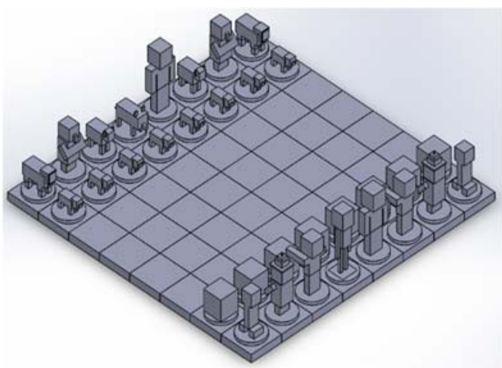
Chess Style	Peer Evaluation Score	Instructor Score
Wireframe chess Set	80.6 %	87 %
Minecraft Chess Set	87.2 %	83.5 %
Medieval Chess Set	82.8 %	81.5 %
Modern Chess Set	60.5 %	80 %
Classic Chess Set	66.5 %	79.5 %
Traditional Chess Set	73. 5 %	71 %

According to the Table 2, scores received through peer evaluation did not show a direct correlation with the instructor scores. This was attributed to the fact that instructor considered all the requested tasks in the grading rubric for evaluating the projects, whereas student evaluations were solely based on the quality of presentations and 3D models. Chess pieces designed by some of the groups (i.e. Minecraft and medieval styles) were not suitable to be produced by 3D printing method due to excessive supports required during printing. Classic, traditional and modern chess sets were among the best candidates for 3D printing, however not many advanced features were used in the aforementioned designs. Wireframe chess set was chosen to be 3D printed due to its unique style, detailed features and suitability for 3D printing.

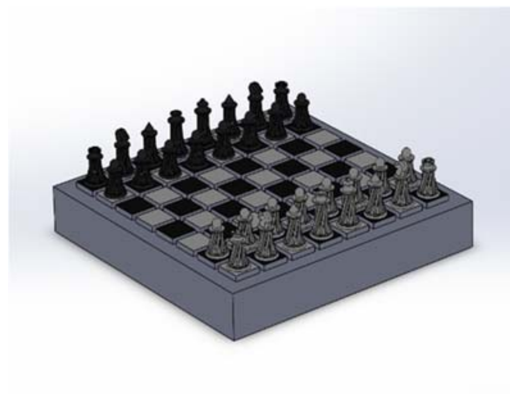
In most of the projects, correct dimensioning techniques were used, though some dimensions on chess pieces with intricate design were intentionally left off by students to enhance clearness of the drawings which does not raise any issues in manufacturing by 3D printing. The 3D models, PowerPoint presentations and working drawing packages consisting of conceptual hand sketch, assembly and detailed drawings were electronically submitted by students on Canvas. The common mistakes in the submitted documents were:

- Hand sketch was not included in the submitted documents or critical dimensions were missing on the hand sketch.
- Tolerencing was not indicated on the drawings or bill of materials was not included in the assembly drawing.
- 2D sketches used for creating 3D models were not fully defined or 3D models were not suitable for 3D printing.

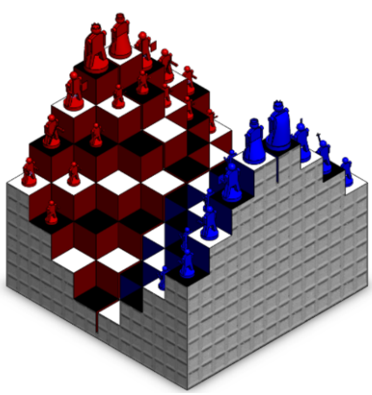
Individual reports showed all students were effectively participated in the final design project.



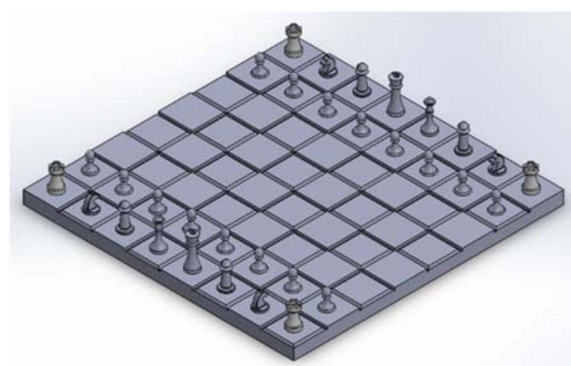
(a) Minecraft style



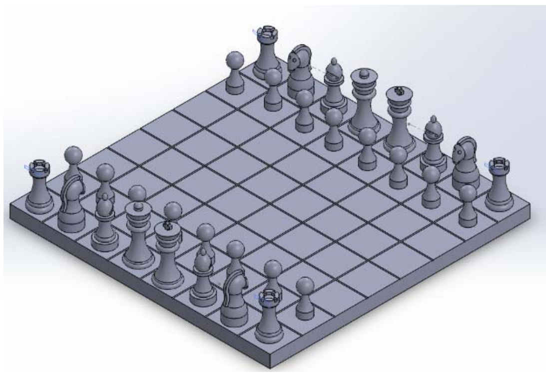
(b) Wireframe style



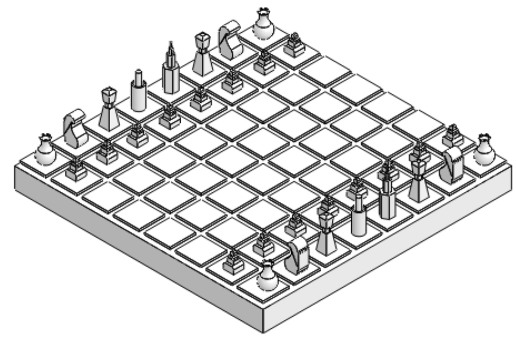
(c) Medieval style



(d) Classic style



(e) Traditional style



(f) Modern style

Figure 1: Different chess sets designed by students

Conclusions

Incorporating effective computer lab sessions to the curriculum of the engineering graphics course is one of the most important means to help students to acquire well-rounded skill sets for using a CAD system. Students learn theoretical concepts and engineering graphics fundamentals during lecture time and then have the opportunity to use SolidWorks to create 3D models, part drawings with appropriate dimensions and tolerances, assembly drawings and bill of materials. Final project is devised to provide a unique platform for students to use all design principles and 3D modeling techniques they have learned through the semester in a group-based project. They also practice on presentation skills to convey the merits of their designs. Based on the personal observation of the authors, the current curriculum of CAD course and laboratory have been very effective, and it has been successfully translated into action in CAD final projects and capstone design projects.

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