Proc. 2nd Saudi Sci. Conf., Fac. Sci., KAU, 15-17 March 2004. Part III, pp 93-101 (2005 A.D./1425 A.H.)

Use of Solid Modeling and Team Skills in Engineering Graphics

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ABSTRACT. Methods of teaching engineering drawing are undergoing fundamental changes, driven by the new requirements of concurrent engineering design. Traditionally, the lecturer needs to perform laborious work in order to enable the students to visualize different projections and perspectives of the models. The use of computer graphics, supplemented with animation capabilities, heralds certain advantages over conventional lectures and laboratory sessions. In addition, the use of such facilities familiarizes the students with computer systems, and enables them to visualize complicated models. In this work, experience gained from the use of the SOLIDWORKS package in the first course in engineering graphics is reported, where the package was used extensively as a tool for teaching. Coping with the current trend in using CAD packages in education, it is suggested that SOLIDWORKS can be regarded as an essential tool for students to be used early during their academic study. It was found that students gained a sound appreciation in solid modeling ability, and developed teamwork skills, presentation skills, and the feedback were highly positive. It is worth mentioning that the course material is being prepared for use for university electronic learning (e-learning) by KAAU.

Introduction

Currently, everyone in the field of engineering and engineering technology education has been affected by the push for outcomes assessment caused by EC2000 and the proposed TAC/ABET criteria (Newcomer *et al.*, 2001). The engineering graphics curriculum is needed to be modified in order to move teaching students from primarily on drafting boards with manual instruments to the use of new tools and methods of representing objects through computer-aided drawing (CAD) (Clark & Scales, 2001a and 2001b). Computer technology is enabling engineers and technicians to design and manufacture parts without relying on two-dimensional drawings.

The curricula at many universities still spend a great deal of time focusing on 2D manual drafting and detailing drawings (Branoff *et al.*, 2001). There are several possible reasons why some programs have not changed to curricula that focus on constraint based, three-dimensional solid modeling. One obstacle to this type of change has been the cost of hardware and software. Some constraint-based programs can cost hundreds of thousands of dollars and cannot realistically be purchased or set for the department in the budget. Another constraint could be due to lack of staff members and engineers to run this kind of

program. However, within the last several years, the cost of the programs has come down (Miller, 1999). Some 3D modeling programs are currently as low as $150.0 per student, even the overseas versions. Moreover, the network version may cost as low as $5000 for 50 seats. Thus, cost can no longer be an excuse for not including 3D modeling into introductory courses (Nasman, 1999).

Another excuse for not revising the curriculum has been that students must understand 2D geometry before entering a 3D environment. Branoff *et al.* (2001) proposed revisions to his Introduction to Solid Modeling course based on national trends in engineering graphics in both industry and education. The topics included in the revised course included visualization, sketching, solid modeling, constraint-based modeling, geometry, dimensioning, multiple views and pictorials, manufacturing processes, working drawings, sectional views, auxiliary views, and assemblies of solid models. Although some of the contents of the course reflect a "drawing centered" design process, the focus of the new course is on model creation and extracting information from the solid model.

Industry leaders have realized the potential of using the 3D model as the center of the design process. Now engineering graphics and technical graphics educators must adjust the curriculum to prepare able practitioners to address industry's current set of demands (Branoff & Hartman, 2001).

Materials and Methods

The engineering graphics course offered by the Production Engineering Department is a service course for all engineering programs at KAAU. The first current course is offered, in many ways, as it was 20 years ago, a one-hour a week lecture and 5 hours of lab work. Students entering an engineering program would not, typically, own a drafting/drawing table or have space for it in their dorm room. The graphics course would usually have a large number of lab hours for student coursework. In addition to a graphical communication course, many programs have, in the last five years, instituted a course to bring students up to speed on current office products such as, spreadsheets, relational database managers, word processing and presentations. This introductory course would be for either little or no credit, but required for graduation.

At KAAU, such an introductory course is called Engineering Graphics I (a two-credit course) and is offered each term by a diverse number of faculties and engineers from many disciplines, but never in a team format. Individual instructors would add their own flavor to the course but the continuity of course coverage is not manageable or predictable. The new Engineering Graphics course will cover the current Engineering Graphics course, the Introduction to Engineering Course, and the Introduction to Solid Modeling course and it will be delivered during two terms. The students will learn the essentials of solid modeling using the full version of SolidWorks. Solid modeling techniques such as wire frame, shapes (bosses, cuts, holes) and operations (fillets, chamfers, shells) that are combined to build parts, extruding (boss/base), revolving, sweeping and lofting are essential elements of the course. Course projects have been developed to reinforce the materials described during the lecture.

The SolidWorks software also has the ability to generate 2-D drafting and detail drawings for manufacturing. Geometric dimensioning and tolerancing, materials and examples from disciplines other than ME, such as circuit boards and plant layout, will be included to enable students from the EE and IE departments to design models. Many

entering engineering students do not have a strongly developed skill set in either 2-D or 3-D visualization. These examples, drawn from their chosen field of endeavor, should motivate their sense of understanding. Team projects and designs are included as a significant portion of the new course. In addition, this course will serve the department as part of the student communication skill set.

In the new College of Engineering curriculum, all engineering students are required to take an introductory course in Graphics. Approximately 120 students take a second course of graphics each semester, which include students majoring in the Mechanical and Civil programs. This curriculum design reflects the concurrent engineering design model and it is expected to meet the needs of future engineering graphics curricula. While many faculties in engineering agree that this type of a model is useful, there still seems to be a strong focus on traditional engineering graphics methods.

The process of teaching the first introductory course of Engineering Graphics have been done into four stages:

1- Usual traditional 2D manual drafting and detailing, which lasted for more than 20 years.
2- Applying 3D solid modeling using SolidWorks 2000 on 14 students only (No 2D drawings, only free hand sketching. Most of these students had failed in the 2D manual drawing course), while all other students are using 2D drawing.
3- Applying 3D Solid modeling using SolidWorks 2001 on more than 80 students (No 2D drawing, only free hand sketching, all are new students)
4- Applying 3D solid modeling using SolidWorks 2001 on more than 40 students after they completed the first 7 weeks on 2D drawings.

It is worth noting that applying 2D CAD using AutoCAD-14 and then AutoCAD-2000 has already been applied (for almost the last 7 years) only on the second course of engineering graphics and only for a limited number of students. This was mainly due to the lack of enough number of machines for all students. However, currently almost 75% of the students are taking the second level of Engineering Graphics using AutoCAD 2000, and it will be upgraded to AutoCAD 2004 in the coming year.

Results

Being able to clearly visualize objects remains a major impediment to engineering students at King Abdulaziz University who are enrolled in engineering graphics courses. Most students can adequately master the 2D and 3D software tools available in the classroom. Even the best students readily admit that the barrier to even better performance was tied to how well they could visualize the part and its details in order to be able to sketch or use CAD to create the necessary views. Typically, new students of varying skill levels have little difficulty drawing and sketching simpler real objects placed before them. They have considerably more difficulty translating 2D technical drawings into a full understanding of the objects represented by these drawings. Their previous courses and life experiences have typically not provided much development of the types of visualization skill. Use of easy to use 3D model viewers is to visual thinking, as training wheels are to bicycling, and as alphabet blocks are to reading. Activities derived from use of these viewers include informed pictorial sketching of readily available "virtual" objects, reinforced understanding of orthographic view conventions, spatial relations, spatial orientation, and spatial visualization.

Since most designs do not involve a single part, it is important for students to understand how to work with multiple parts in small and large assemblies. Currently, the course emphasizes assemblies as well as application of assemblies, and strives to give complete understanding on how one part interacts with other parts in the assembly. An important consideration for this course will be the treatment of assembly components at an operating-system level and hope to direct influence of the associative characteristics of a constraint-based modeling tool on the geometry modification process. Students will be asked to model existing objects and to create solutions to unique problems with an understanding that a critical attribute of their solution should be its ability to be modified.

Term projects were executed in teams. Each team was required to have a leader. Each team of 3-5 students was required to look for different projects. Any assembled project should have at least 6 parts. All parts should cover most of the commands and features taught during the class. At the end of the term, each team was required to put the parts together in an assembly, and to present their work using Power Point, and every student in the team should present his own work. At this level, students were not required to submit multiview and pictorial sketches or working drawings of individual parts. By performing such projects the students were expected to be able to know the interaction of each part with the others, and allow each part to have a dynamic motion if possible.

Figure 1.1 shows a set of students' sample class works, from the beginning of the term until the end of the term. Some of the more promising samples of the final term projects are shown in Fig. 1.2.

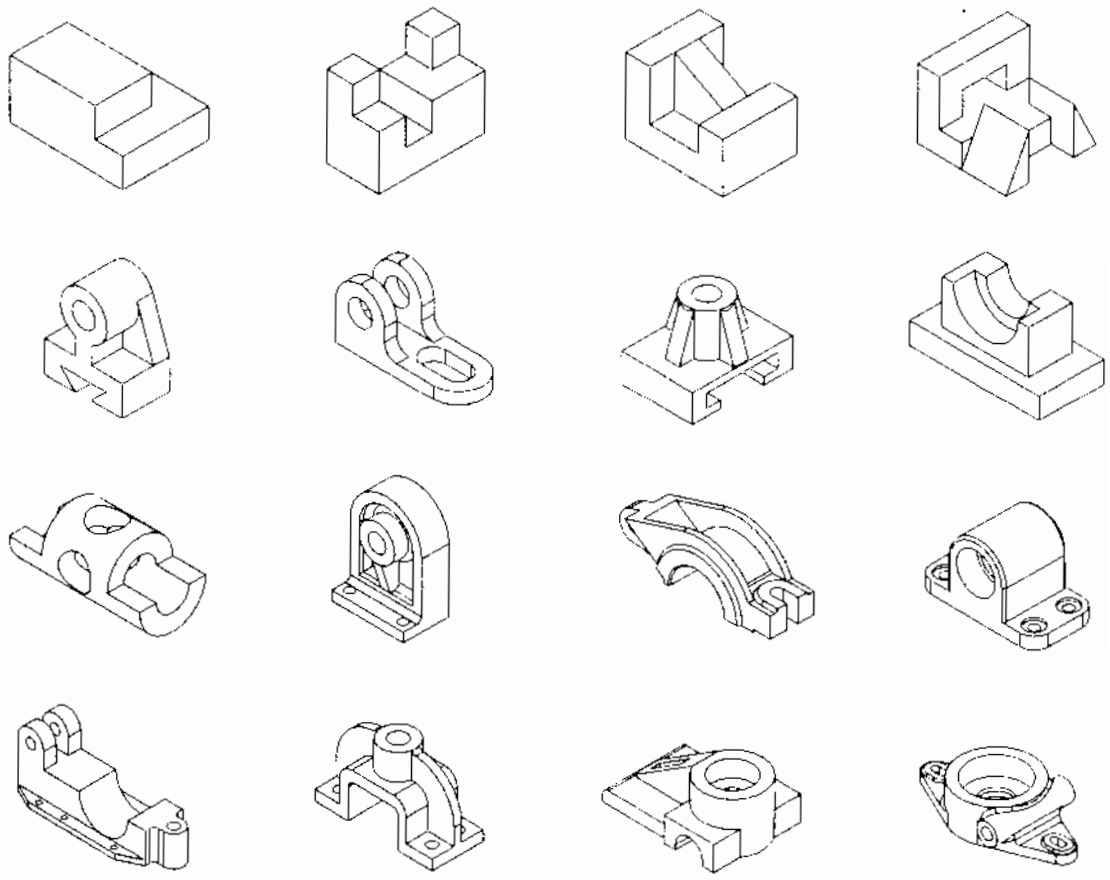

Fig. 1.1. A sample set of class work produced during the semester.

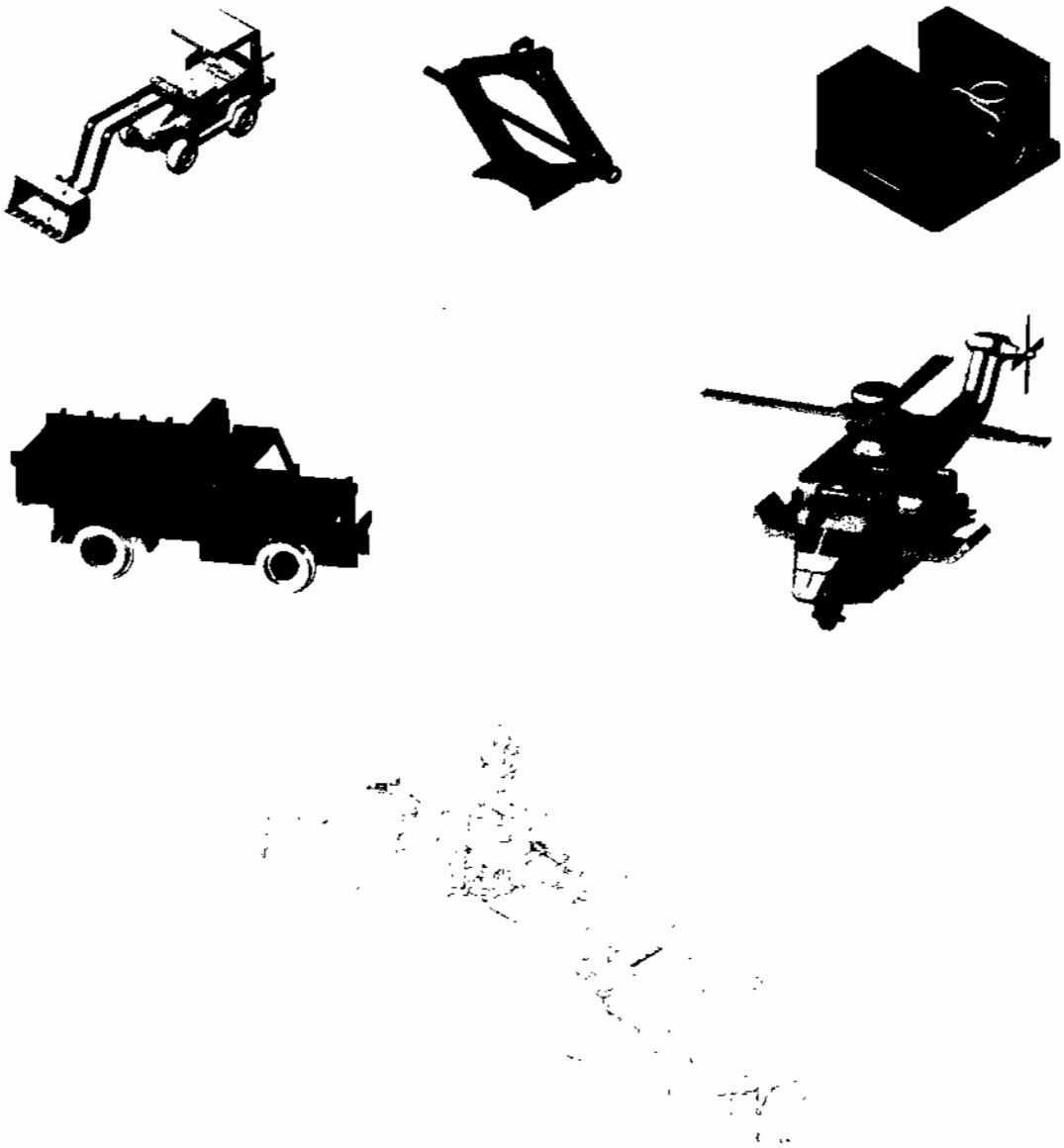

Fig. 1.2. A sample set of final term projects.

In summary, the positives of the course were viewed as follows:

- Coping with the world trend of moving toward CAD.
- An essential tool that the student gets at an early stage to be used during their academic study.
- Early stage of possessing tools such as:
  - Solid modeling ability.
  - Team works skills.
  - Presentation skills.
- Preparing E-learning materials such as:
  - 3D models, easier to visualize.
  - Power Point lectures.

- Practicing Visual Basic software.

- Students are motivated due to the following reasons:
  - Using computers is fun for students.
  - Building 3D shapes is challenging.
- The course generates much interest:
  - Discussions between students becomes more confined to the course material.
  - It becomes difficult to push them out at the end of the class period.
  - The student to staff ratio is low.

There are a few aspects that need improvement, such as:

- Some of the objectives listed below were not achieved:
  - Technical report writing.
  - Free hand sketching.
  - Dimensioning.
  - The AutoCAD software package.

There are certain other obstacles, such as:

- Some students do not have any prior experience with computers (Coming from villages).
- Some students do not have access to computers at home or in the dorm.
- There is a natural resistance to change.
- For projects with a small number of parts, the leader ended up doing all of the assembly himself.

The feedback from the students can be summarized as below:

- Generally, students rated SolidWorks above average in ease to use. Also, those students who spent more time in doing all exercises and the extra works gain more knowledge to finish the project. Some students are ambitious to discover more on attempting to do more advanced tasks.
- Many students recognize the value of sketching and they found that the CAD SolidWorks software is a very interesting part of the course.
- In some cases student response to work in teams was positive especially for projects with large number of parts, and they felt that learning objectives were achieved.

Discussion and Conclusions

- The first course in Engineering Graphics must be revised to cope with the world trend. By utilizing the visualization capabilities of solid modeling systems, it is hoped that students will be able to better understand basic concepts taught in the first graphics course while having more opportunities to use the solid modeling systems for other courses, especially the mechanical design courses.
- Different classroom examples for the same course reflect different outcomes.
- The first example stage cited above is not really representative since most of the students had already been exposed to 2D manual drawings. However, this trial

reflects the importance of utilizing the visualization capabilities in performing many complicated projects.

- The second stage, that is applying 3D solid modeling to all new students, shows also the importance of utilizing the visualization capabilities. In addition, the students are required to do some hand sketching as several studies have indicated that hand sketching improves visualization skills. However, almost all the students are lacking the capability of free hand sketching.

- The third stage, which we believe is the most successful, is to increase emphasis on free hand sketching. Thus teaching, during the first 5-6 weeks, all students free hand sketching, and then the rest of the course on 3D solid modeling. This shows that emphasis is appropriate and many students become proficient in free hand sketching as well as in 3D solid modeling, and they can easily visualize most of the parts in isometric views.

- The introductory engineering classes, associated with large numbers of students, are challenging. Upwards of 300 students per term will be taking the introductory classes. The physical resources necessary for this effort are significant and must be highly efficient. Due to lack of both enough machines and staff members, yet another trial will be conducted next year, where 2D drawing will be taught during the first 3 weeks and then, shifting to 3D solid modeling every other week.

- A dynamic website is required for the course to keep communicating project and course requirements and other information to students.

- The use of computers in engineering education has continued to increase. Many entering engineering students at KAAU are often more fluent in software like Microsoft Office than the Faculty. Computers are also used as one of the many tools engineering students need in their course work. These issues present serious problems for faculty that teach graphics using traditional techniques.

- As educators preparing the next generation of engineers and technologists, it is our responsibility to put aside our misgivings, fears, and prejudices, and give our students the education that they need and deserve.

- In order to keep with the world trends, the Engineering Graphics Program should also continue in:

- Web technologies.
- Simulation and animation.
- Internship.
- Collaboration.
- Study of current trends.

and it should include:

- Macro programming.
- Data translation.
- File and data management.
- CAD standards.
- Constraint-based solid modeling.

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استخدام نمذجة الأجسام ثلاثية الأبعاد في الرسم الهندسي

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المستخلص. طبقا للمتطلبات الحالية لمنهج التصميم الهندسي فقد تم عمـــل تغيـــرات جذرية في طرق تدريس مادة الرسم الهندسي. فالمحاضر يبذل جهـــدا كبيـــرا لكـــي يستطيع الطلاب أن يتخيلوا المساقط المختلفة والمنظور لنماذج ثلاثية الأبعاد.

إن الرسم بمساعدة الحاسب الآلي المدعوم بإمكانية تحريك النماذج يمتاز عـــن طرق التدريس العادية في جعل الطالب ملماً بأنظمة الحاسب وتخيل الكثير من النماذج المعقدة.

في هذا البحث تم توضيح الخبرة المكتسبة من استخدام برنـــامج Solidworks وبشكل كبير في تدريس مادة الرسم الهندسي بكلية الهندسة. وتماشيا مع الاتجاه العـــام في استخدام برامج الرسم والتصميم بمساعدة الحاسب CAD فقد تـــم إدراج برنـــامج Solidwork كأداة أساسية في تدريس مادة الرسم الهندسي في المـــستوى الأكـــاديمي الأول. وقد لوحظ اكتساب الطالب مهارة جيدة لنمذجة الأجسام ثلاثية الأبعاد ، وتطوير مهارات العمل الجماعي ، ومهارات الإلقاء والاتصال.

وجدير بالذكر أن تجهيز المادة العلمية بالطريقة الحالية يمكن الاستفادة منه في التدريس في الجامعة الإلكترونية بجامعة الملك عبدالعزيز .