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Using Computer Technology Tools to Improve the Teaching-Learning Process in Technical and Vocational Education: Mechanical Engineering Subject Area

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Abstract: This paper discusses the integration of computer assisted instructions (CAI) with traditional class room teaching. It describes a teaching method to bring real-world of industrial work into the classroom that underscores the need to learn fundamental principles while adding excitement and relevance to the experience. This paper presents results of a case study undertaken to understand the effect of computer assisted teaching methodology on learning effectiveness in classroom environment. The effects of computer assisted instructions on different levels of cognition of individual learners have also been evaluated. The computer aided drawing (CAD), computer aided manufacturing (CAM) and computer numerical control (CNC) courses at the Bahrain institute are an integral part of this attempt. These courses emphasize the development of a 3-D geometric computer model and application of this digital database to all phases of the design process. The students make freehand sketches, build computer models, mate assemblies of parts, perform various analysis, create kinematics simulations, generate final design drawings, import engineering drawing as DXF file, generate NC file to build rapid prototypes as shown in the table 1 below.

Keywords: Computer Technology, C.N.C and AutoCad Software

Table 1: Activities and Learning Outcomes

Module No	Activities and learning outcomes / Modules
Module 1	**(computer sketching creation of design & drawing).** Set up the sketch plane units and grid parameters; demonstrate all 2-D sketching primitives; demonstrate all line editing features; make simple extrusions and revolutions to get 3-D geometry.Demonstrate the creation and editing of dimensions; set geometric constraints; make simple extrusion and revolution to get 3-D; render the parts.
Module 2	**(computer sketching modelling utilities).** Create 3-D parts; add feature-based, parametric design features; use advanced sweep operations; edit the geometry in 3-D; render the part.
Module 3	**(computer sketching assembly modelling and mating).** Create individual 3-D parts; assemble parts as mechanical assembly; mate features as appropriate; check for clearance and interference of parts; create colour rendering of assembly.
Module 4	**computer sketching (engineering drawing).** Create section views in 3- D and 2-D; create individual 3-D parts; make different 3-D section views of the parts; export acceptable colour image files of 3-D section views for presentation purpose. Project 2-D section views of model; incorporate the 2-D section views into a technical drawing.Generate and dimension three-view drawing on a suitable drawing sheet style; add centrelines where appropriate; dimension the drawing; add a title block and appropriate notes. Save each part as DXF file.

Module 5	**Rapid prototyping (using data exchange format- DXF and setup check and final manufacturing).** Create cutting parameter for each part (cutting tool, tool size, tool materials, and work materials). Generate tool paths for different layers for each part (X, Y, Z direction, cutting loop, and depth of cut, feed and speed). Save each part as numerical control (NC) file and send the file to the prototyping machine. Set the work piece; set the tool at zero position; check direction of rotation for the chuck and the cutter; check the work piece and the cutting tool is securely clamped; verify the NC program for any shaft and any gear, and simulate the motion of assembly file of the shaft and gear; run the machine and then the program (C.N.C).
Module 6	**Project and Analysis (manufacturing).** Generate final checklist for prototype (dimensions, assembly, motion, tolerance and fit). Submit final report of the project.

SHORT PRE- AND post-surveys were conducted about the specific learning activities for the modules in selected sections of the course. These short surveys were started during the fourth week of the course. Once the students had become confident with the modelling software, a second larger survey was conducted across all models at the end of the course. This survey dealt with student learning outcomes, and focused on how the "Engineering CAD/CAM/CNC" course contributed to improvement in these important student skills and abilities and also in increasing the efficiency of tools used in teaching and learning process to transfer knowledge.

The results indicated that computer technology used as instruction tool helps students achieve learning out comes at all levels of cognitive domains in all five modules. The surveys showed a positive trend in learning. This is to be expected, since the students gained some additional knowledge and skills doing each exercise, and appropriately reported that in the surveys.

Introduction

The engineering education and practices being adopted therein are changing at a very fast rate. The visual and simulation capabilities of computer aided teaching materials and inherent flexibility in their use have forced educators to develop computer assisted instructions (CAI) to assist in teaching and learning process **[1, 2, 3]**. The specific advantages offered by computing resources in a typical learning process are quick calculations, data storage and dynamic simulations. It has been shown that computing resources when properly and strategically integrated with existing teaching methods can result in dramatic improvement in learning experience of students **[4, 5, 6]**. A lot of literature is currently being published on improving effectiveness of e-learning to widen its base and acceptability. At the same time traditional teaching techniques are being modified to satisfy stringent quantitative quality requirements.

In mechanical engineering education, especially in CAD/CAM subject area, there is a need to understand the mechanics of learning process from learners point of view **[1, 5, 6 , 7]** to satisfy learning outcomes requirements. The aims and objectives of the modules in this subject area are defined carefully to enable students to satisfy workforce requirements in the industry after they gain qualifications **[8, 9, 10, 11]**. In CAD/CAM/CNC subject area the various learning skills are as shown in table1**.**

The integration of computer assisted instruction tools with traditional classroom teaching in area of mechanical engineering education is required to achieve all the learning skills. It was an attempted teaching method in this study to bring real-world of industrial work into the classroom that underscores the need to learn fundamental principles while adding excitement and relevance to the experience **[12, 13, 14, 15].**

The computer aided drawing (CAD), computer aided manufacturing (CAM) and computer numerical control (CNC) courses at the Bahrain institute are an integral part of this attempt. This course emphasizes the development of a 3-D geometric computer model and application of this digital database to all phases of the design process. The students make freehand sketches, build computer models, mate assemblies of parts, perform various analysis, create kinematics simulations, generate final design drawings, import engineering drawing as DXF file, generate NC file to build rapid prototypes. An assessment of student outcomes in the courses was conducted in the fall 2005 (2^{nd} semester) and 2006 (1^{st} semester) using a series of self-reported learning surveys, assignment results, and final examination results of the project work. This paper analyses the examples of class work that support the learning activities and presents the results of these surveys.

Activities Proceed

An engineering student activity is an exercise that usually requires integrating several tasks to achieve a defined goal. It can be an individual project or a team project, or even some form of a combination of both. The Mechanical Engineering Department at the Bahrain institute (Sh.Khalifa Bin Salman institute) has embarked on systemic educational reform. This curriculum reform is an attempt to bring real-world work into the classroom that underscore the need to learn fundamental principles while adding excitement and relevance to the experience.

Modularization and Assessment of Engineering CAD/CAM/CNC

To facilitate approach of this research, the Mechanical Engineering curriculum has been organized into a set of learning modules with specific educational outcomes. Table 1 lists the current modularization scheme and learning outcomes. It consists of six modules with each module having an individual student project that is conducted at the conclusion of the course.

With this modularization scheme, the six individual modules train students to develop computer/technical skills and abilities that can be later used in reality of industrial work.

These modern course outcomes, as outlined in Table 1, were fully implemented during the course fall 2005 (2nd semester) and 2006 (1st semester) using computer laboratory with three different teaching methods and three groups of students.

1. Group 1 (traditional teaching method) with 15 students.
2. Group 2 (computer assisted instruction integrated with teaching method) with 15 students.
3. Group 3 (supervised/unsupervised exposure to computer simulation integrated with teaching method) with 15 students.

The initial modules stress individual learning activities, which build the students' confidence in going from 2-D to 3-D solid geometric modelling. Once their confidence in computer graphics modelling is established, the students explore many design applications for the 3-D model. In doing so, they experience the concurrent engineering paradigm that underscores the course. Several computer graphics exercises are available for each module, thus allowing the students some choice in the objects they model and analyze. All objects selected for the exercises are real parts taken from commercial catalogues, or actual parts from the shop. With the pedagogy and learning objectives established, the next step was assessment of the learning activities in the course. Two types of preliminary assessment metrics were gathered.

Short pre- and post-surveys were conducted about the specific learning activities for the modules in selected sections of the course. These short surveys were started during the fourth week of the course, once the students had become confident with the modelling software. A second, larger survey was conducted across all models at the end of the course. This survey dealt with student outcomes, and focused on how the "Engineering CAD/CAM/CNC" course contributed towards improvement in these important student skills and abilities and also efficiency of tools used in teaching and learning process to transfer knowledge (quality of instruction material, software and instruction manual).

Student Outcomes Study (Module 1&2): 3-D Solid Modelling

The first student outcomes study focused on the feature-based 3-D solid modelling unit. The learning objectives for this module included: learning basic 3-D features like extrude and revolve; creating advanced 3-D features like shell and sweep; inserting reference geometry planes; mirroring 3-D features; creating linear and circular 3-D patterns; Create 3-D parts; Add feature-based, parametric design features; Use advanced sweep operations; edit the geometry in 3-D and editing features like fillets. Typical objects for these student exercises are shown in Figures 1 (Bracket) and 2 (Pulley). Other choices for modelling were also available.

Figure 1 bracket

Figure 2 Pulley

Before the students started the module, a short survey form (**Pre**) was completed and submitted.

The survey asked the students to rank their *level of understanding* of the following seven concepts:

1. Types of design features available in 3-D solid modelling,
2. Creating design features in 3-D modelling,
3. Editing design features in 3-D modelling.
4. 4 Set up the sketch plane units and grid parameters;
5. Demonstrate all 2-D sketching primitives
6. Demonstrate the creation and editing of dimensions.
7. Make simple extrusion and revolution to get 3-D; render the parts.

In the same survey the students in *module two* were asked to rank their *level of understanding* of the following three concepts:

1. Create 3-D parts;
2. Add feature-based, parametric design features;
3. Use advanced sweep operations; edit the geometry in 3-D

The response scale for the answers to the questions was:

5 (Exceptional), 4 (Good), 3 (Average), 2 (Below Average), 1 (None).

After the module exercises were completed, the same survey form (**Post**) was completed and submitted to the teacher. The students were also encouraged to list things they both liked and did not like about the exercise. Results of the two surveys were compared using the pre- and post- average rankings for these questions across the participating sections (student sample size G1 N=15), (G2 N=15), (G3 N=15). The average rankings for all questions increased in the post- survey except questions 4 and 5 in traditional method, as indicated in Table 2 below and in the bar chart 1.

Table: 2 Survey 1 (Module 1) Results (G1 N=15), (G2 N=15), (G3 N=15)

No	Pre-Ranking			Post-Ranking			Difference (Post-Pre)		
	G1	G2	G3	G1	G2	G3	G1	G2	G3
1	0.14	0.20	0.18	0.16	0.26	0.22	**0.02**	**0.06**	**0.04**
2	0.16	0.20	0.21	0.16	0.25	0.24	**0.00**	**0.05**	**0.04**
3	0.13	0.23	0.22	0.14	0.28	0.25	**0.01**	**0.05**	**0.04**
4	0.18	0.23	0.26	0.17	0.27	0.28	**-0.01**	**0.04**	**0.03**
5	0.15	0.28	0.28	0.14	0.31	0.29	**-0.00**	**0.03**	**0.01**
6	0.15	0.29	0.29	0.16	0.32	0.32	**0.01**	**0.03**	**0.02**
7	0.19	0.26	0.26	0.19	0.30	0.29	**0.00**	**0.04**	**0.03**

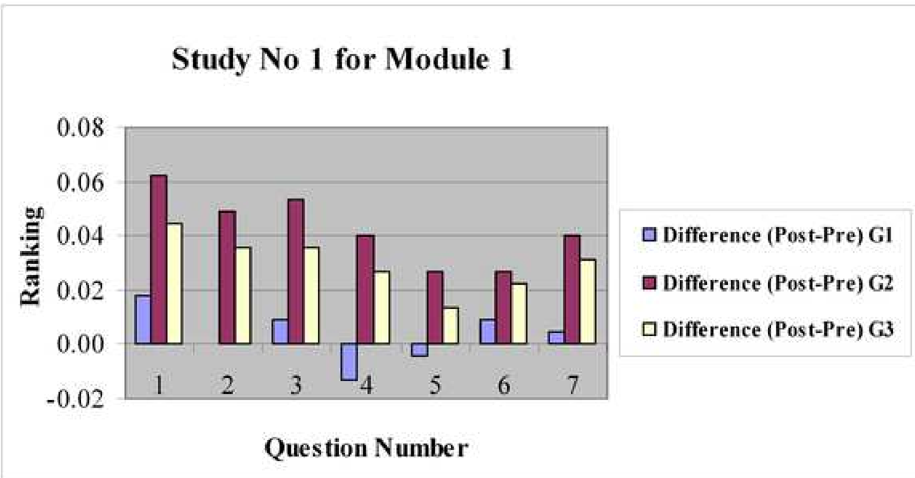

Chart 1: Results of Study 1(Module1) (G1 N=15), (G2 N=15), (G3 N=15)

Table 3: Survey 1 (Module 2) Results (G1 N=15), (G2 N=15), (G3 N=15)

No	Pre-Ranging			Post-Ranking			Difference (Post-Pre)		
	G1	G2	G3	G1	G2	G3	G1	G2	G3
1	0.15	0.26	0.26	0.16	0.30	0.29	0.02	0.04	0.03
2	0.13	0.24	0.22	0.16	0.30	0.27	0.03	0.06	0.04
3	0.17	0.25	0.23	0.20	0.30	0.27	0.03	0.05	0.04

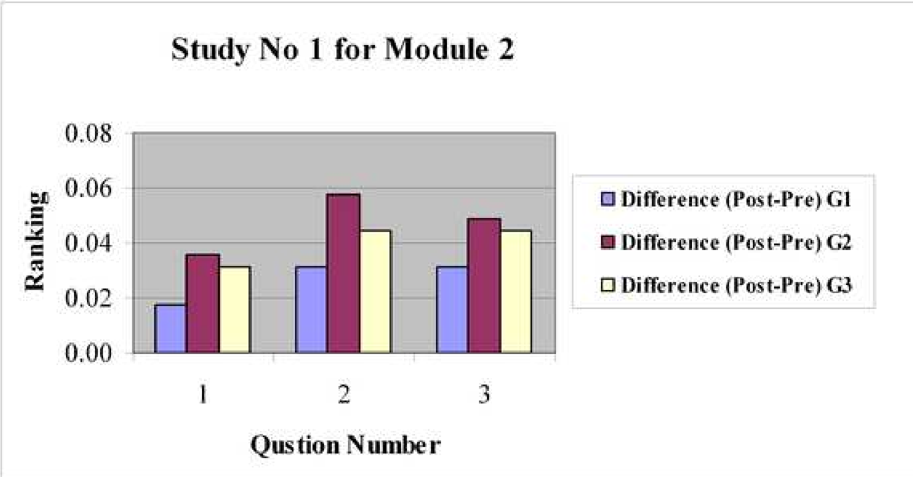

Chart 2: Results of Study 1(Module2) (G1 N=15), (G2 N=15), (G3 N=15)

The positive increases in the rankings, for all seven questions in (module1) and three questions in (module2) chart 2, indicate that the student learning outcomes were achieved, at least as self-reported by the students. More importantly, the students listed several common themes about what they liked about the exercises and software used to support their learning:

- They were real-world examples, not abstract.
- The software was easy to use and many features were learned.
- The visualization controls were very useful with computer technology support.
- Easy to follow the task procedure in simulation and computer assisted instruction methods.
- Easy to link classroom work during practicing time in the laboratories.
- Give students opportunities to work extra time with and without teachers' supervision by using computer guide.

On the contrary, the students in traditional teaching almost commented on the lack of clarity in the written notes, book, and projector slides which were still in traditional form which affect their results. Nonetheless, the general tone of the group 2 and 3 students' written responses was quite positive for this first study.

Student Outcomes Study 2 M 3(Module 3): Assembly, Mating Modelling and Kinematics Animation

The next survey was conducted for the assembly and mating modelling. The learning objectives for this laboratory exercise were: building multiple 3-D parts that will mate together; starting a new assembly file; dragging and dropping parts into the assembly; moving and rotating components; and mating the parts with different mate types.

The student outcomes study was concerned with kinematics animation. For this module, the students either build a new assembly of solid model parts or use a previously built assembly (i.e. see study 2). While the software offers elaborate tools for creating motion pathways for animating 3-D models, a simple approach was taken in this exercise. Once the parts are properly mated into an assembly, the students use an "Explode Assembly" command available in the software. The parts are then exploded along nominal pathways as shown in Figure 3. Next they use an "Edit Path" command for each part to create a new animation schedule. Finally they play the animation on an external viewer, and then save it in a universal.DXF file format.

A typical student exercise consists of building the assembly is shown in Figure 3 before and after mating.

Figure 3: Pulley bracket assembly and Kinematics Animation

For this assembly module, the students learn how to change the colours of the assembly components and how to apply several mate conditions: parallel, concentric, coincident, and distance. They can also get a colour hardcopy of the whole assembly once the exercise is completed. As before, a pre- and post-survey was conducted for the student learning outcomes (*level of understanding*) posed by the following seven concepts:

1. Building individual and multiple parts in 3-D solid modelling and render the part.
2. Building an assembly of parts in 3-D solid modelling.
3. Mating parts in 3-D solid modelling.
4. Check for clearance and interference of parts.
5. Create colour rendering of assembly.
6. Exploding a 3-D assembly of solid model parts.
7. Creating a kinematics animation of a solid model assembly.

The same ranking scale of 5 (Exceptional) to 1 (None) was used again. Results of the pre- and post ranking averages are shown in Table 4 and in the bar chart No: 3

Table 4: Survey 2 (Module 3) Results (G1 N=15), (G2 N=15), (G3 N=15)

No	**Pre-Ranging**			**Post-Ranking**			**Difference (Post-Pre)**		
	G1	**G2**	**G3**	**G1**	**G2**	**G3**	**G1**	**G2**	**G3**
1	0.15	0.26	0.26	0.16	0.30	0.28	**0.01**	**0.04**	**0.02**
2	0.14	0.27	0.26	0.16	0.30	0.29	**0.02**	**0.04**	**0.03**
3	0.16	0.28	0.28	0.19	0.31	0.30	**0.02**	**0.03**	**0.02**
4	0.15	0.27	0.27	0.14	0.29	0.29	**-0.00**	**0.02**	**0.02**
5	0.16	0.30	0.31	0.17	0.32	0.32	**0.01**	**0.03**	**0.01**
6	0.15	0.26	0.25	0.16	0.28	0.27	**0.01**	**0.03**	**0.02**
7	0.16	0.28	0.28	0.18	0.31	0.31	**0.02**	**0.03**	**0.02**

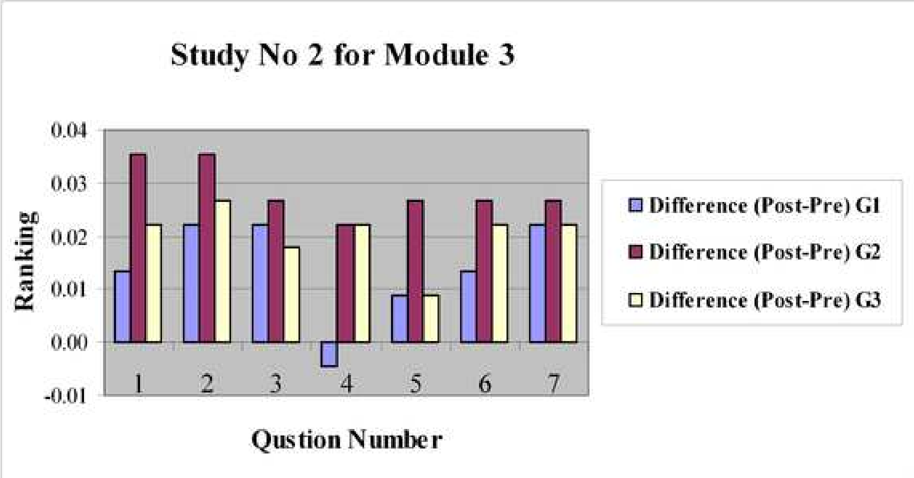

Chart 3: Results of Study 2 (Module3) (G1 N=15), (G2 N=15), (G3 N=15)

Again the difference between pre- and post- average rankings indicates a positive trend for all seven concepts. In particular, the students commented that the exercise was real-life and that they liked assembly, mating modelling and kinematics animation mating for mechanical parts. The results show that most of the students in the group 2 and 3 were familiar with module number 3 because of computer simulation and teacher instruction or computer instruction. In traditional teaching method some students commented about one difficulty that was; it was hard to identify a rotate control function without any guide or support during practice, which is not an intuitive skill for the students. Results of the pre- and post-ranking averages are shown in Table 4 and in chart 4.

Once again, the differences between the pre- and post- average rankings indicate a positive increase in the general learning activities, averaging almost +0.03 point for group 1, +0.05 for group 2, and +0.04 for group 3 increases for all seven questions except question 4 which shows post result lower than the pre result.

It has been noticed that sometimes the students do not have enough knowledge to assemble and mate the parts since the main teaching method is based on traditional learning. Students do not always have opportunity to work with teacher support.

The students exit comments for this animation study were all very positive.

Student Outcomes Study 3(Module 4): Generating and Dimensioning Three-View Drawings and Section Views in 3-D and 2-D

The third study focused on the need to generate an engineering drawing for final design documentation. The learning activities and objectives for this module included: inserting a drawing sheet onto the screen; setting the drawing sheet options; projecting three orthographic views of a solid model onto a drawing sheet; adding centrelines; dimensioning the drawing; adding title block and annotations; printing the drawing and then save it as DXF file format.

A typical student computer modelling exercise is shown in Figure 4, and its projected and dimensioned engineering drawing is shown in Figure 5.

Figure 4: A 3-D Computer Model

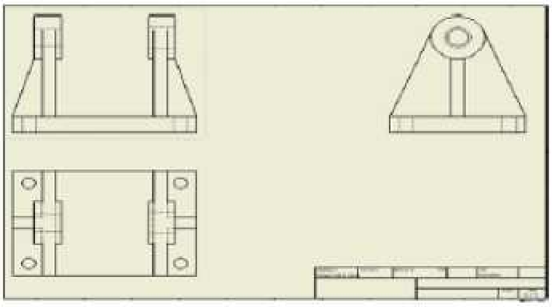

Figure 5: A Dimensioned Drawing of a 3-D Model

The study also focused on the topic of section views, focusing on both 3-D and 2- D techniques.

The pre- and post- surveys for study 3 posed the following eight questions concerning the student's level of understanding about:

1. Making a 3-D section view of a 3-D solid model.
2. Making a 2-D section view from a 3-D solid model.
3. Detailing a 2-D section view drawing.
4. Arranging the three-view layout on a drawing sheet.
5. Dimensioning a three-view drawing.
6. Generate suitable drawing sheet style.
7. Add a title block and appropriate notes.
8. Save each part as DXF file.

Results of the pre- and post- ranking averages are shown in Table 5

Table 5: Survey 3 (Module 4) Results (G1 N=15), (G2 N=15), (G3 N=15)

No	Pre-Ranging			Post-Ranking			Difference (Post-Pre)		
	G1	G2	G3	G1	G2	G3	G1	G2	G3
1	0.14	0.26	0.25	0.12	0.30	0.27	**-0.02**	**0.04**	**0.02**
2	0.15	0.29	0.28	0.13	0.31	0.29	**-0.02**	**0.02**	**0.01**
3	0.14	0.30	0.29	0.15	0.32	0.30	**0.00**	**0.02**	**0.01**
4	0.17	0.26	0.26	0.17	0.30	0.29	**0.00**	**0.04**	**0.03**
5	0.16	0.29	0.29	0.14	0.32	0.31	**-0.02**	**0.04**	**0.02**
6	0.16	0.28	0.29	0.16	0.31	0.31	**0.00**	**0.03**	**0.02**
7	0.18	0.30	0.30	0.19	0.32	0.32	**0.01**	**0.02**	**0.01**
8	0.28	0.32	0.32	0.29	0.33	0.33	**0.01**	**0.01**	**0.01**

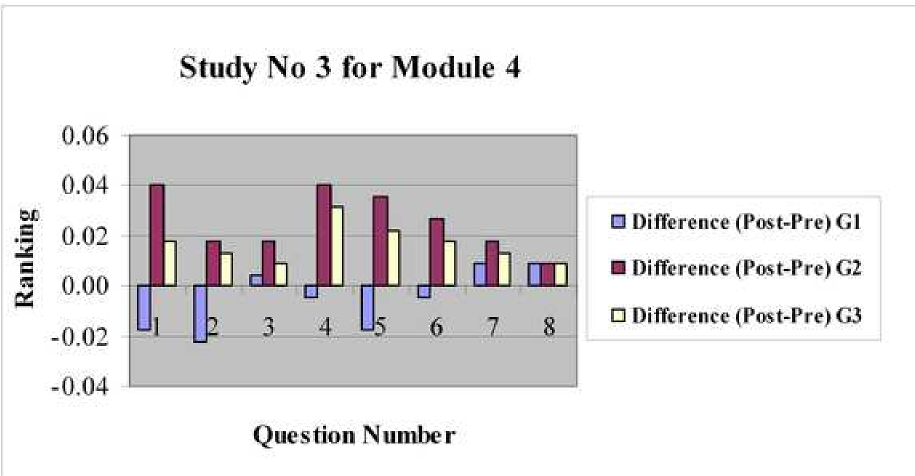

Chart 4: Results of Study 3 (Module4) (G1 N=15), (G2 N=15), (G3 N=15)

Again, the differences between the pre- and post-average rankings indicate a positive increase in the general learning activities in simulation and computer assisted instruction (group 2 and 3), although it may not be as the differential as in previous studies.

The students in group 2 and 3 were generally receptive to learning activity, even though they realized that making an engineering drawing is relegated to a secondary role in the modern concurrent engineering paradigm. They frequently commented on the "ease" of creating three-views from a solid model with the current software. They also felt that the last two modules reinforced the basic concept of deriving design documentation from a solid model, rather than creating the documentation from scratch. The one consistent negative comment was the degree of difficulty in applying details to the final engineering drawing, particularly in placing centrelines and in deciding which dimensions to select. The final comment was that the software packages able to develop student's skills and improve learning experience.

On the other hand the group 1 students (traditional teaching) comment was difficult to develop their knowledge in complex drawing specially in learning outcome 1, 2, and 5 as ranking result shown in table 5 and chart 4.

Saving their work as DXF file that could be played externally, this was particularly gratifying since none of them had ever made a DXF file before. The instructions were easy to follow, due mainly to the" Animation Wizard" and accompanying tools that were available in the software.

Student Outcomes Study4 (Module5): Rapid Prototyping

The fourth study was conducted during the rapid prototyping lab exercise. The learning activities for this module included: building a solid part; creating NC file from the solid model data; transferring the DXF file to a rapid prototyping machine as NC file; and completing the rapid prototype. Some example parts used as student exercises for this module are shown in Figure 6.

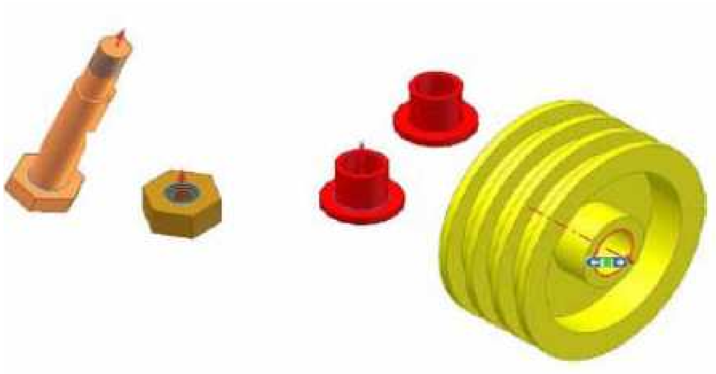

Figure 6: Rapid Prototypes of Student Parts

The pre- and post- surveys posed the following eleven questions concerning the student's level of understanding about:

1. Generating DXF and NC file from a 3-D solid model.
2. Building a rapid prototype of a 3-D solid model.
3. The role of rapid prototyping in the design process.
4. Create cutting parameter for each part (cutting tool, tool size, tool materials, and work materials).
5. Generate tool paths for different layers for each part (X, Y, Z direction, cutting loop, and depth of cut, feed and speed).
6. Save each part as numerical control (NC) file and send the file to the prototyping machine.
7. Set the work piece; set the tool at zero position.
8. Check direction of rotation for the chuck and the cutter; check the work piece and the cutting tool are securely clamped.
9. Verify the NC program for simple shaft complex prototype.
10. Simulate the motion of assembly file.
11. Run the machine and then the program.

Results of the pre- and post- ranking averages are shown in Table 6 and in Chart 5.

Table 6: Study 4 (Module 5) Results (G1 N=15), (G2 N=15), (G3 N=15)

No	Pre-Ranging			Post-Ranking			Difference (Post-Pre)		
	G1	G2	G3	G1	G2	G3	G1	G2	G3
1	0.16	0.25	0.25	0.18	0.28	0.28	**0.02**	**0.03**	**0.03**
2	0.14	0.24	0.24	0.12	0.28	0.27	**-0.03**	**0.04**	**0.02**
3	0.15	0.28	0.28	0.16	0.31	0.31	**0.02**	**0.04**	**0.03**
4	0.14	0.21	0.21	0.12	0.25	0.25	**-0.02**	**0.04**	**0.04**
5	0.11	0.20	0.20	0.12	0.28	0.25	**0.01**	**0.08**	**0.05**
6	0.20	0.31	0.31	0.19	0.33	0.32	**-0.01**	**0.02**	**0.01**
7	0.13	0.26	0.26	0.13	0.29	0.28	**0.00**	**0.04**	**0.02**
8	0.20	0.31	0.31	0.17	0.33	0.32	**-0.03**	**0.02**	**0.01**
9	0.16	0.26	0.26	0.14	0.29	0.28	**-0.02**	**0.04**	**0.02**
10	0.18	0.29	0.29	0.16	0.32	0.31	**-0.02**	**0.03**	**0.02**
11	0.30	0.32	0.32	0.30	0.33	0.33	**0.00**	**0.01**	**0.01**

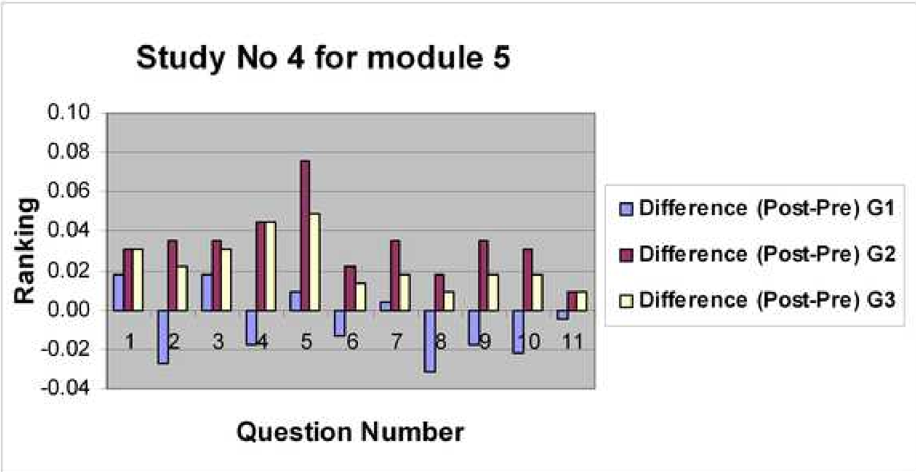

Chart 5: Results of Study 4 (Module5) (G1 N=15), (G2 N=15), (G3 N=15)

Once again, the differences between the pre- and post- average rankings indicate a positive increase in the general learning activities, averaging around +0.03 point for group 2 (computer assisted instruction) and +0.02 point for group 3 (computer simulation) increase for all eleven questions.

In general, the students enjoyed this module even though it was time-consuming due to the manual assembly requirements of the rapid prototyping system. They clearly enjoyed building a real part when they tried to match with a computer model. As one student simply stated, “seeing the computer sketches turning to an actual model was very impressive.” Most of the students in this module said that the computer assisted instruction software gives opportunity to deal with complex components with simplest methods.

Around -0.01 point the average, indicate negative results obtained from eleven question of prototype module for traditional teaching method. The students commented with main points about the negative results of this module saying “The student's attention in the classroom was not there, there was no motivation for the students to create their interest in the subject matter and develop positive attitude toward learning”. To manufacture mechanical components in the work shop need student’s attention all the time for interactive knowledge.

Student Outcomes Study 5(Module 6): Project and Analysis (manufacturing)

The study of fifth outcome dealt with finite element analysis (manufacturing). An example exercise used was a Gear and shaft assembly to illustrate the usefulness of manufacturing to analyze and improve upon a design. The students first built and assembled the solid parts as 3D solid modelling using computer aided drawing (CAD). The next stage was to build real mechanical components in the lab.

They assigned different type of measurements with different measuring tools to compare between engineering drawing sheet and the real components.

The checklist for the drawing is always available to show the areas that need improvement in the shaft and gear design. The students then complete the exercise by modifying the design. In this case, they need to repeat the above procedure to improve manufacturing design. Some example parts used as student exercises for this module are shown in Figure 7.

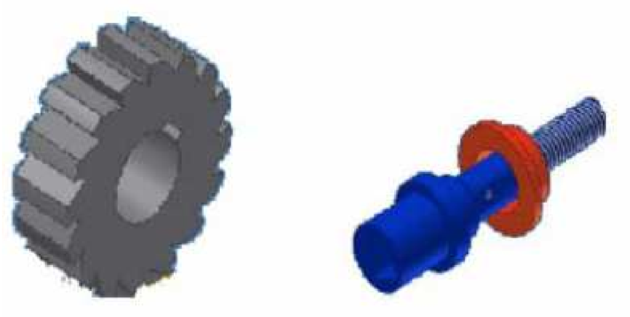

Figure 7: Manufacturing component (Shaft and Gear)

The pre- and post- surveys posed the following four questions concerning the students' level of understanding about:

1. Generate final checklist for dimensions.
2. Generate final checklist for assembly.
3. Generate final checklist for motion.
4. Generate final checklist for tolerance and fit.

Results of the pre- and post ranking averages are shown in Table 7 and in the bar chart No 6.

Table 7: Survey 5 (Module 6) Results (G1 N=15), (G2 N=15), (G3 N=15)

No	Pre-Ranging			Post-Ranking			Difference (Post-Pre)		
	G1	G2	G3	G1	G2	G3	G1	G2	G3
1	0.16	0.26	0.26	0.13	0.29	0.27	**-0.03**	**0.03**	**0.01**
2	0.13	0.25	0.25	0.15	0.28	0.27	**0.02**	**0.03**	**0.01**
3	0.16	0.25	0.25	0.13	0.28	0.27	**-0.02**	**0.03**	**0.02**
4	0.12	0.20	0.20	0.14	0.24	0.22	**0.02**	**0.04**	**0.02**

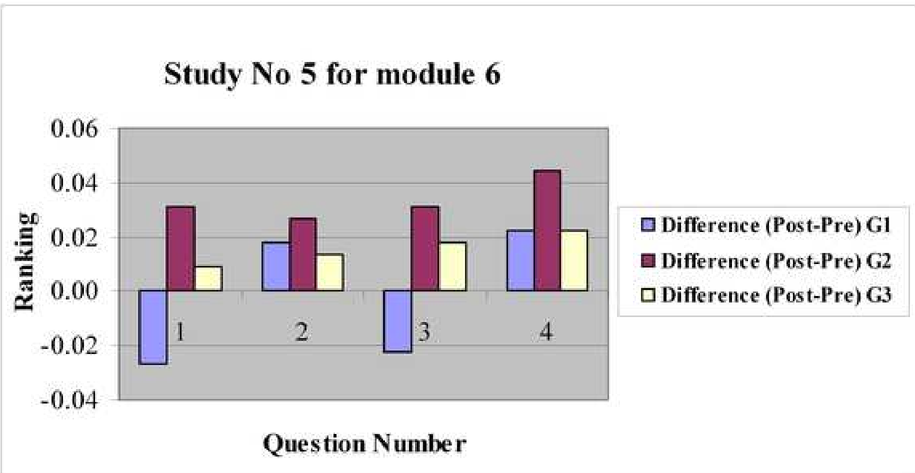

Chart 6: Results of Study 5 (Module6) (G1 N=15), (G2 N=15), (G3 N=15)

Again, the differences between the pre- and post-average rankings indicate a positive increase in the general learning of element analysis of 3D solid model and manufacturing components (at least in the context of exercise as self-reported by the students).

The average ranking indicate a positive increase in the learning activities averaging around +0.03 point for group 2 (computer assisted instruction) and +0.02 point for group 3 (computer simulation) increase for all the four questions.

The group 2 and group 3 students mentioned that the teaching methodology gives opportunities to understand the following aspects:

- The need to carry out many design tasks systematically and that design of the manufacturing process should be carried out in parallel with drawing analysis.
- Produce and more importantly read fully detailed engineering drawing and manufacturing, dimensions, assembly, motion, and tolerance and fit using engineering checklist.
- The need to search may obtain skills and information appropriate to the task under consideration in which student may not possess ability of analysis.
- Analyse a product and subdivide it to produce a product structure upon which drawing set and task allocation may be based..
- Read fully detailed engineering drawing and diagrams.

Also for this study, the students offered the following favourable comments:

- The visualization of detailed engineering drawing and manufacturing, dimensions, assembly, motion, and tolerance and fit using engineering checklist as results was great.
- Seeing the assembly, motion, and tolerance and fit using engineering checklist was helpful to understand the study.
- Very real-like engineering design example.

The main negative comment seemed to be amongst the students in the traditional teaching: the wasting time behind the finite element method which remained elusive to them after the exercise was over, even though they did not see the potential for its application or understand the way of analysis with checklist. One student commented while leaving the room: "This was a great exercise, but I still don't know what I did." This aspect of the manufacturing module needs to be improved as these types of advanced topics are introduced in the course. To achieve good ranking and to increase average from low rank to high rank, the method of teaching and learning should be improved.

Comparison of Six Module of Student Learning Outcomes Surveys

All six module student learning outcomes surveys showed a positive trend in learning, based on self reported pre- and post- module exercise surveys. This is to be expected, since the students gained some additional knowledge and skills doing each exercise, and appropriately reported that in the surveys. Table 8 lists the average pre- to post- increases.

It can be noted that study 2 (assembly, mating modelling and kinematics animation) had the largest gain in self-reported learning, with an average increase of 0.05 ranking points in teaching with support of computer technology, The study No1: 3-D (Solid Modelling) was the second with an average increase of 0.04 . The other studies in group 2 and group 3 were with an average varying from 0.02 to 0.03. The study No 4: (Rapid prototype) had the lowest net gain of just -0.01 ranking points in the tradional teaching method. In most of the study of students' outcomes, the traditional teaching recorded low average marks. It was not surprising that in simulation and computer assisted instruction marks were higher since the students already had received enough knowledge during first six week of exposure to the modelling software before the surveys were initiated. A comparison of all the studies indicates that the advanced method (simulation and computer assisted instruction) of teaching CAD/CAM/CNC was most appealing to the students and hence students showed a bigger gain in the pre- to post- level of understanding of the topic. This underscores the students' enthusiastic reception of these modern, technology based topics in their course of engineering drawing and manufacturing. Also it can be concluded that teaching with the help of computer technology enhances students learning.

Table 8: Average Pre- to Post Increases

Study	**Average**		
	1G	**2G**	**3G**
Student Outcomes Study 1 (Module 1&2): 3-D Solid Modelling	**0.00**	**0.04**	**0.03**
Student Outcomes Study 2 (Module 3): Assembly, Mating Modelling and Kinematics Animation	**0.03**	**0.05**	**0.04**
Student Outcomes Study 3(Module 4): Generating and Dimensioning Three-View Drawings and Section Views in 3-D and 2-D	**0.01**	**0.03**	**0.02**
Student Outcomes Study4 (Module 5): Rapid Prototyping	**0.01 -**	**0.03**	**0.02**
Student Outcomes Study 5(Module 6): Project and Analysis (manufacturing).	**0.00**	**0.03**	**0.02**

Conclusions

The mechanical engineering "Engineering Drawing and manufacturing" curriculum has evolved continuously to present system in which Computer aided drawing CAD, Computer aided manufacturing CAM and computer numerical control CNC, are at the centre of instruction system. Table 1 lists a sequence of engineering CAD/CAM/CNC learning modules that systematically introduce the students to this new engineering drawing and manufacturing paradigm.

Pre and post surveys have been used to present the results of systematic assessment of the learning outcomes of this new approach to "Mechanical Engineering Drawing and manufacturing." Three teaching method and two types of assessment were conducted. Specific learning activities for six drawing and manufacturing modules were identified and formulated into a set of surveys. The surveys were conducted in three selected sections of the mechanical engineering (CAD/CAM/CNC) course using self-reported pre- and post-study rankings.

In all cases, the difference between the post and pre- ranking score, deemed improvement in learning, showed a positive trend in group 1 and 2. This indicates that all the drawing and manufacturing activities resulted in a positive learning experience on the part of the students and the highest values of the most learning outcomes were obtained in groups 2 and 3 (simulation teaching method and computer assisted instruction method).

Also it has been seen that the group (2) exposed to computer assisted instructions performed much better than the group exposed to traditional teaching. Further computer assisted instruction helped students with widely varying pre-learning abilities to satisfy various learning outcomes in CAD/CAM/CNC subject area.

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