Session 3148

Assessment of Performance for Engineering Technology Students on Computer-Aided Engineering Software Usage

Daniel Chen
Central Michigan University

I. Introduction

Today, most of the computer-aided engineering (CAE) software packages available in the market are more intuitive to use. It is easier for one to know what the software is doing with visual feedback at every step. Although these window-driven software are becoming more sophisticated in terms of capabilities, they are expected to be easier to learn. It is ideal for an engineering technology student to acquire the CAE skills , because a CAE software can provide very accurate results without dealing with in-depth theories and complex mathematical calculations. Many students in engineering technology have already had the experience in this area. They have started taken the courses which incorporate CAE software. The purpose of this study is to assess their learning outcomes via the evaluation of classroom and laboratory performance.

At Central Michigan University, the CAE course was originally developed eight years ago for mechanical engineering technology majors. Nevertheless, more students in both industrial technology and computer-integrated manufacturing (CIM) today want to take this course even it is not required for their majors. Most of the industrial technology students in CAE class had a concentration in mechanical design and engineering graphics. CIM is an interdisciplinary major that requires twenty-four credit hours each from industrial technology and computer science. Since the students enroll in the CAE class have quite diversified backgrounds, it would be interesting and beneficial to find out how well each student group has learned due to its specific background. The goals of this study can be fulfilled by answering the following two questions: (1) Do engineering technology students have necessary skills to perform CAE work at the completion of the course? and (2) How well do engineering technology students perform as a group? The comparison is made among the groups of engineering technology, industrial technology and CIM. The assessment was primarily based on the quantitative evaluation of each group's performance from the tests and laboratory work.

II. Performance in Finite Element Analysis

Since students were required to complete all assignments for the CAE class using application software SDRC/I-Deas, the assessment of students' performance was, therefore, focused on the usage of I-Deas for engineering analysis [1]. It included the topics in finite element analysis (FEA) and mechanism design. FEA is a simulation process that predicts stress and deflection by dividing the structure into a grid of "elements" to form a model of real structure. Figure 1 shows the procedure required for completing such a process using I-Deas. The evaluation was carried out in a number of areas according to the flowchart in Figure 1. These areas include: (1) FE Model Create & Model Solution, (2) Boundary Conditions, and (3) Meshing.

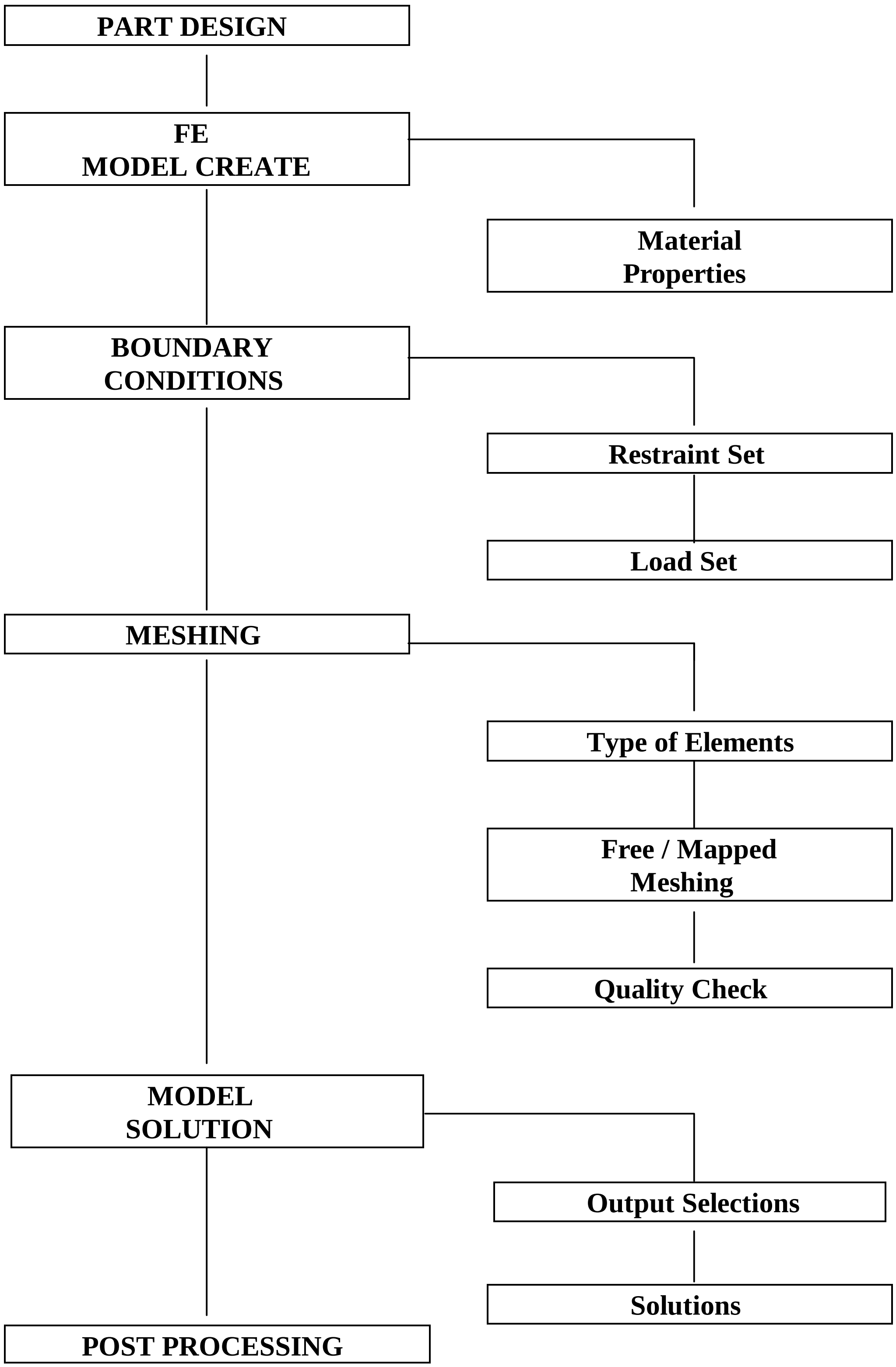


Figure 1. Flowchart of FEA Procedure

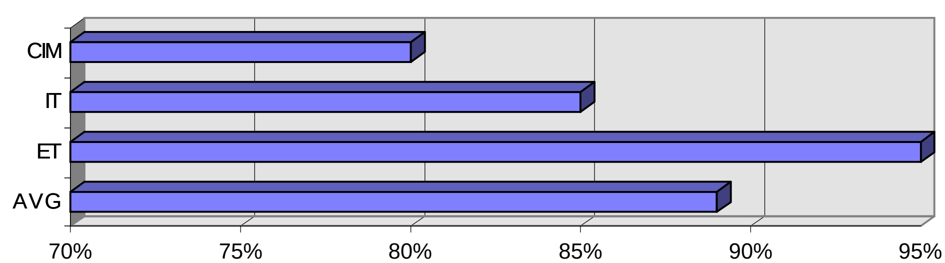
Each area of the FEA process has its own function [2]. How did a student perform in one specific area primarily relied on his or her prior coursework relative to that area. Part Design, which is basically solid modeling of parts and has already covered in the lower-level computer-aided design class, was not included in the evaluation. Post-processing was not included either, because it only provides tools to display the results after the FEA solution is completed. Students' ability of interpreting the results from Post-processing was not included in the evaluation.

Area of FE Model Create & Model Solution

FE Model Create and Model Solution were combined because both require a solid knowledge base in mechanics of materials. Students need to know how to carry out the FEA process, which begins with FE Model Create. It allows an identified material to be assigned to a part. The material properties, such as modulus of elasticity and Poisson's ratio, can be specified in the material table provided. Students must determine which method to use for modeling the part next. If creating a mesh and boundary conditions based on geometry was necessary, the option of "Geometry Based Analysis Only" must be selected. If a polynomial function was necessary, the switch of "P Element Analysis" could be turned on to allow the use of a polynomial equation within the element. This means that even with a fewer number of larger elements, the convergence is an automatic part of the solution. The Model Solution task is where the finite element model is solved. It has a number of standard types of analysis that can be performed, which include linear and non-linear statics, linear buckling, heat transfer, and potential flow. This study focuses on linear statics only, because this CAE course serves only undergraduate beginners. Model Solution allows students to select the types of outputs as the results of solution. Stress and deflection are the most common outputs by default. Other outputs like reaction force and element force can be added to the list if necessary.

Figure 2 shows how each student group did in FE Model Create and Model Solution based on the maximum of one hundred percents. The class average (AVG) is also provided for the comparison. The figure indicates that engineering technology (ET) group performed in this area by far the best. Most of engineering technology students had already taken the courses of Mechanics of Materials and Machine Element Design. These courses helped them to have a better understanding in material property and relationship among stress, deflection, and external loading.

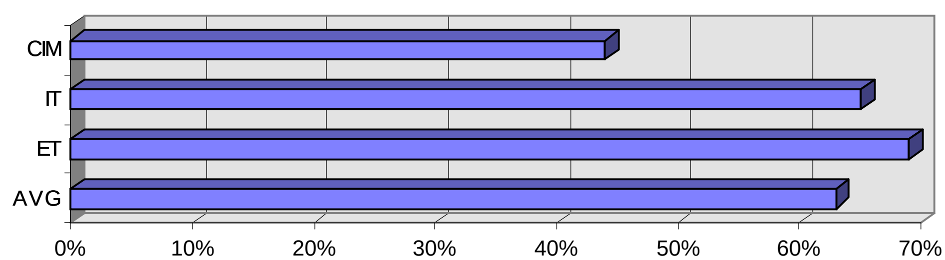
Figure 2. Performance in FE Model Create & Model Solution



Boundary Conditions

The Boundary Conditions task deals with the loads and restraints applied to the part. Students had to be familiar with different types of load. A load can be either a concentrated force or a distributed pressure. A load can also be a temperature difference or an energy source. Restraints have six values that include three translations and three rotations. Students must know how to deal with each entry, which can either have a value for the fixed displacement or be left free to move. If the geometry, restraint, and loading are all symmetric, it is often possible to model only half (or even quarter) of the part. Students encountered this situation quite often, because a large number of FEA problems had parts with the symmetry condition. The difficulty was how to apply the correct restraints to allow the displacements on the symmetry plane of the half model to be identical to that of the entire model. Although the experience from prior coursework helped, it was very common even for a good engineering technology student to make mistakes in this part of process. Figure 3 shows how each student group did in Boundary Conditions. Though the engineering technology students performed the best as a group, they still had some difficulties. This result matches the instructor's laboratory observation, that is, very few could correctly handle the restraints required for the symmetry condition at the first trial.

Figure 3. Performance in Boundary Conditions

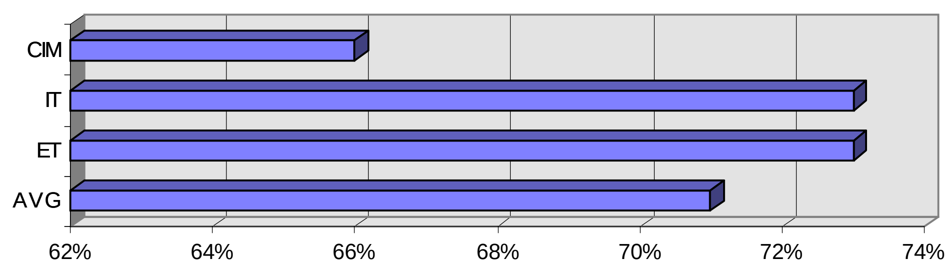


Meshing

The Meshing task is used to create nodes and elements and check the model. Students were instructed what element type to use for a problem - thin-shell, solid, or beam-section. Students were evaluated on how effective they could mesh a model and take the advantage of Quality Check function. Elements are prepared by either free or mapped meshing with the goal to make elements with the minimum distortion and stretch. The objective is to achieve the highest accuracy with the lowest number of elements. Quality Check is a model checking function, which is used to check the shape of all elements generated from meshing. A lower value from quality check indicates that the elements in the model could be distorted or overly stretched. Students were expected to be able to use this tool to determine whether it was necessary to fix the model by completely re-meshing or just repairing one or a few elements. If a re-meshing was necessary, should it be switched from free meshing to mapped meshing? Very often, the accuracy is closely tight to how a cut-out feature, such as a hole or a notch, is mapped meshed. Figure 4 shows how each student group did in the area of Meshing. Though the CIM group gave the worst performance, the engineering and industrial technology groups had about the same level of performance that was far from the perfect.

Because a significant number of problems required mapped meshing, and it was not easy for an amateur to perform such an operation. The improvement in this area must rely on experience.

Figure 4. Performance in Meshing



III. Performance in Mechanism Design

Mechanism Design computes the geometric properties including displacement, velocity, and acceleration for a mechanical mechanism [3]. Few products designed today do not have moving parts. Mechanism design allows the designer to put the solid-based parts of a machine into motion without actually building one. Under these simulated motion conditions, parameters such as limits of motion, interference, and the geometric properties can be analyzed. Figure 5 shows the procedure required for the mechanism design process using I-Deas. The students' performance was evaluated with the focuses on (1) Assembly task and (2) Mechanism Design task. As the flowchart shown in Figure 5, the parts constructed in Part Design must be assembled first. Students needed to know how to use assemblies and subassemblies to group the parts in a system according to their specific functions. In Mechanism Design task, revolute, translational, ball, or cylindrical joints were added to the system. Students had to be familiar with types of input motion, which can be either constant or time dependent, assigned to one or more joints. The result produced from the internal solver of I-Deas predicted the motion of the mechanical mechanism which was based on the design provided by the instructor. In terms of display of results, they were expected to be able to generate the graphs of linear (or angular) displacement, velocity, and acceleration that were plotted as a variable of time for any given part.

Figure 6 shows how each student group did in Mechanism Design. The figure indicates that the engineering technology group performed the best in this area. Most of engineering technology students had already taken the course of kinematics and knew how to plot displacement, velocity, and acceleration graphs manually using polygon method or graphical differentiation. After all this time-consuming drafting work required for kinematics, most of them were able to quickly define problems, generate alternatives, and perform design analysis using the software.

IV. Laboratory Performance

The CAE class spends the first ten weeks on FEA and the rest on Mechanism Design for the sixteen-week semester. For the entire semester, students are required to complete at least twenty-

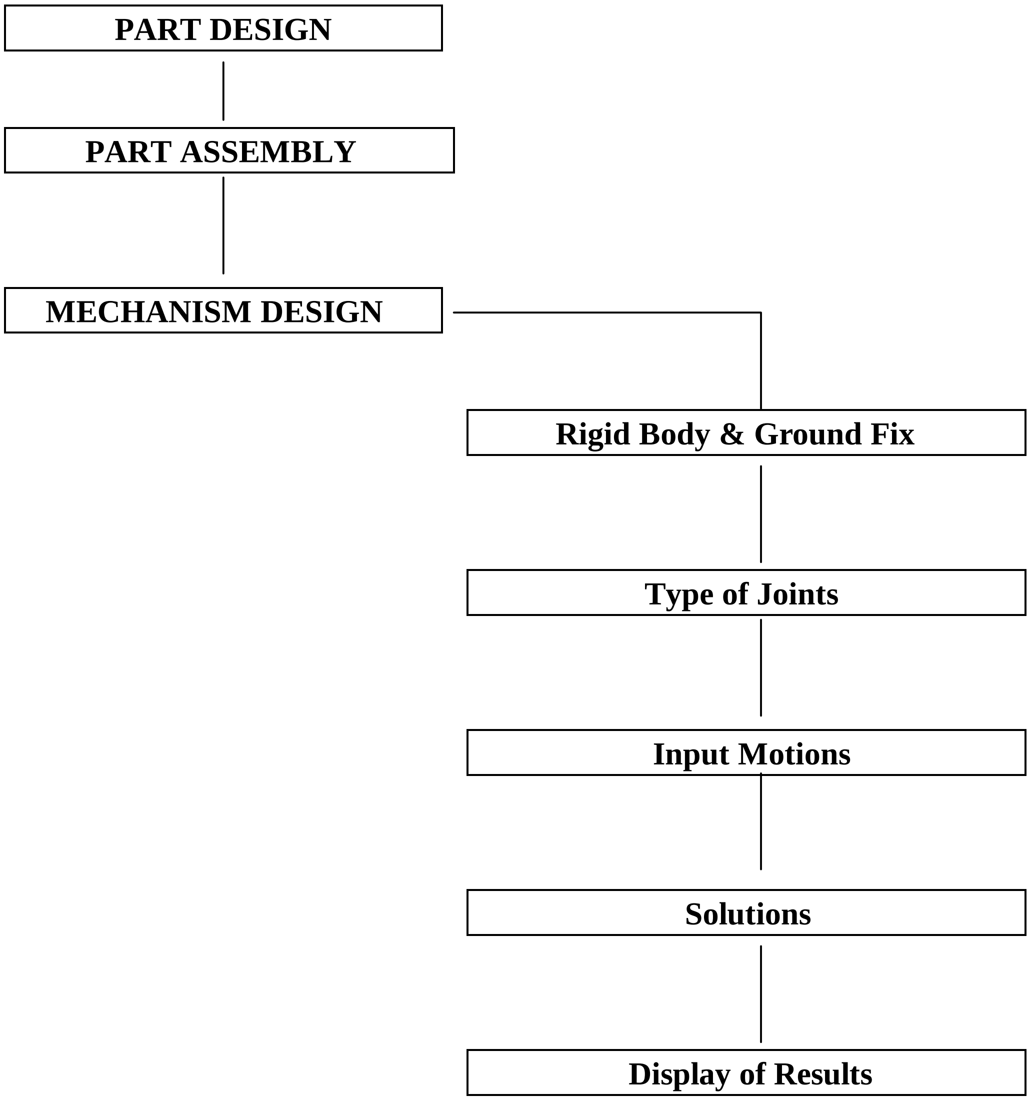
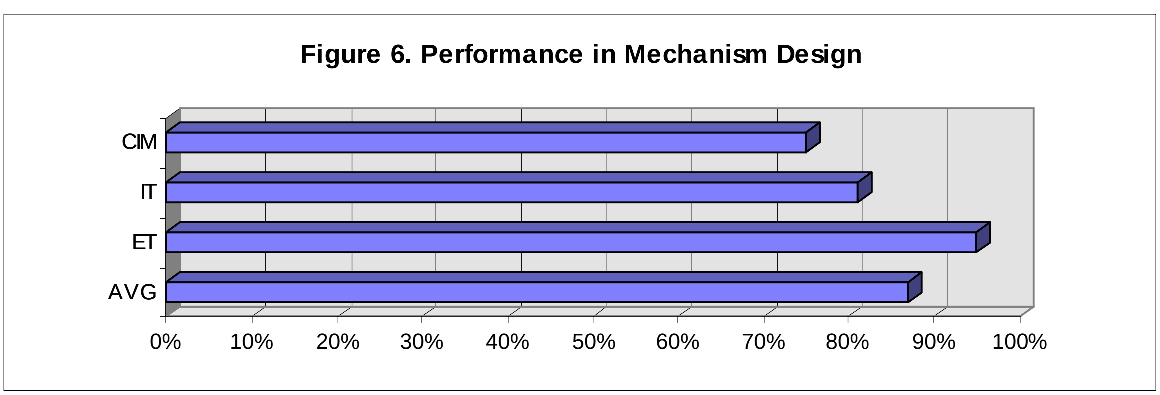


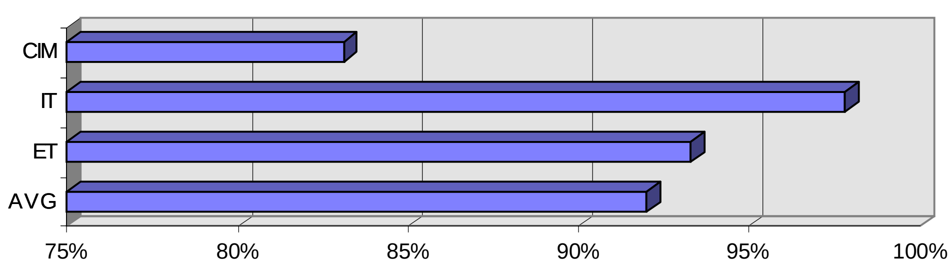
Figure 5. Flowchart of Mechanism Design Procedure



four problems (and one semester project) with two-third of them in FEA and one-third in Mechanism Design. All those turned in usually had been completed successfully. The average amount of time a student spent in the laboratory was about six to eight hours per week. Figure 7 shows how each group did for all assignments on the Sun workstations in the laboratory. The mechanical engineering technology group did very well in this aspect with an average of 93%. This represents a total of 93% on successful completion of all assignments. Most of the unsuccessful works usually occurred at the beginning rather than near the end of the semester. According to the instructor's experience, an average engineering technology student needed assistance often at the first two or three weeks, then he or she was capable of completing the problem alone without much help afterward. This observation was possible because the instructor often sat with students at the computer to offer advice and monitor their skills and physical understanding of the problem.

Figure 7 also indicates that the industrial technology group did the best in laboratory performance. This is probably because that most of them had already completed a series of 2-D CAD courses using I-Deas. These courses include Computer-Aided Drafting, Machine Design Graphics, Tool Design, and Geometric Dimensioning and Tolerancing. Their comfort level with the hardware/software was high comparing to that of the engineering technology group. In addition, the CAE work allowed them to explore the more challenging portion of this same software for which they had been using for long. Although they were required to absorb new concepts and adopt new approaches, they were motivated to give greater efforts for this challenge. The laboratory performance proved that even though industrial technology students didn't have the necessary backgrounds to completely understand and interpret the simulated results, there is no question regarding their ability of using a CAE software.

Figure 7. Laboratory Performance



V. Students' Backgrounds

Table 1 gives the information about the students' backgrounds. It only lists the courses (with credit hours) which would help students deal with CAE work. Students should have completed most of these courses prior to the CAE course. The (mechanical) engineering technology program has a stronger technical background which emphasizes problem solving. The program requires a series of courses in science, mathematics, and CAD in addition to technical science and design. The technical science includes kinematics, dynamics, fluid mechanics, thermodynamics, mechanics of materials, and circuit analysis. The technical design includes machine element design and tool design. The industrial technology and CIM programs have a background which emphasizes computer-aided drafting. Both programs require very little technical science and design that helps one deal with the physical understanding of the CAE problems. This explains why both industrial technology and CIM groups didn't do as well on the tests as the engineering technology group. As a matter of fact, the CIM program's shortcoming in science and mathematics makes the students' learning process for CAE difficult. This can be easily seen in Figures 2, 3, 4, 6, and 7. The CIM students' performance were the worst across all areas.

Table 1. Students' Backgrounds

COURSE	ENGRG. TECH.	IND. TECH.	CIM
Physics Courses	10	5	0
Computer Science Courses	3	0	24
Mathematics Courses	12	6	0
Kinematics, Mech. of Mat., Machine Des.	9	0	0
Other Technical Science & Design Courses	15	3	3
2-D & 3-D CAD Courses	9	18	15

VI. Conclusion

The tests were designed in a way to evaluate a student's learning outcome in each area of FEA and Mechanism Design. They were very effective instruments when used together with the evaluation of laboratory work. According to the instructor's observation, those who could score the same as the class average or better in the tests were capable of carrying out CAE work successfully at the completion of the course. Since the engineering technology students' performance exceeds the class average in all areas, one can conclude that the majority of them ought to be able to deal with this type of work without much difficulty. And their laboratory performance supports this conclusion. Of course, there is always room for improvement even for a good engineering technology student. The areas for improvement include Boundary Condition and Meshing in the FEA process. The operation in each of these two areas, however, involves the experience one has accumulated. The more FEA one is able to work, the more he or she is capable of carrying out these operations without making mistakes. This could be easily seen from their semester-long laboratory work.

Bibliography

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DANIEL CHEN
Daniel M. Chen is an Associate Professor of Industrial and Engineering Technology at Central Michigan University. He has taught various courses in Mechanical Engineering Technology during the last thirteen years. Currently, near half of his teaching load is in Computer-Aided Design/Computer-Aided Engineering. Dr. Chen is a registered Professional Engineer in Michigan. He received his Ph.D. in Mechanical Engineering from Kansas State University in 1984. He received his B.S. and M.S. in that same discipline from Taipei Institute of Technology and South Dakota School of Mines and Technology, respectively.