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Innovations in Freshman Mechanical Engineering Curriculum at New Jersey Institute of Technology*

KWABENA A. NARH and HERLI SURJANHATA
Department of Mechanical Engineering, New Jersey Institute of Technology, University Heights, Newark, NJ 07102-1982, USA. E-mail: narh@admin.njit.edu

This paper describes the Mechanical Engineering contents of a new inter-disciplinary, project-based freshman engineering curriculum at New Jersey Institute of Technology (NJIT). The course, which was run as a pilot when this paper was written, is called Fundamentals of Engineering and has now been approved for the freshman engineering curriculum. The two case-study projects, which constitute the Mechanical Engineering component of the course curriculum, are the Lawn Sprinkler and 3.5-inch Floppy Disk Drive. In this course, the freshman engineering student is introduced to many aspects of engineering as an entire unit working together, with particular emphasis on the concept of teamwork in engineering research projects. Students are introduced to many computer-aided design tools available at NJIT which can be used not only to build models of the product to be manufactured but also for diagnostic analysis in order to solve potential manufacturing problems. The student is also introduced to the concept of communication among team members and the concept of technical report writing and oral presentation. The grading and course evaluation schemes are also discussed. A few samples of students' graphic communications are reproduced.

INTRODUCTION

DURING THE Summer of 1996, from May to the end of August a number of professors from several Departments within New Jersey Institute of Technology (NJIT), met to develop a new freshman engineering curriculum based on a previously prepared course outline. The course outline was developed by a committee from more than twelve departments known as the Fundamentals of Engineering Design/Technology Reinvestment Project (FED/TRP) committee. This new course, known as Fundamentals of Engineering (FE), is a follow-up to the existing NSF-sponsored Gateway Coalition Course called Fundamentals of Engineering Design (FED) which had run for more than three years. In the FED, students are introduced to three distinct modules in one semester, for example Mechanical Engineering Module, Chemical Engineering Module, and Civil Engineering Module. They are always learning two distinct disciplines running parallel during the semester. FE on the other hand, is an interdisciplinary project based course consisting of design and computer applications components. The students in FE work as a team on a number of case-study projects designed in such a way that they introduce the freshman engineering student to a range of fundamental concepts of engineering. In this context, the student is exposed to a wide range of engineering disciplines and applications. The rationale behind this approach is that through multiple exposures to the fundamental concepts and their integration in different contexts, the student will develop a strong grasp of the breadth of engineering and provide a road map to their future studies.

This article describes the Mechanical Engineering component of two of the four projects that constitute the curriculum for the 1996–97 Fall and Spring semesters, and the rationale behind the course content. It begins with the course structure, followed by a detailed description of the mechanical engineering contents of the two projects, including the grading and course evaluation schemes used.

THE COURSE STRUCTURE

The Fundamentals of Engineering freshman course is a project-based two semester pilot curriculum modeled on the NSF-sponsored Gateway Coalition Course; the latter known as Fundamentals of Engineering Design (FED) had run parallel with the FE pilot course but is now replaced entirely by FE. The FE pilot course has two main components: a fundamentals of engineering component and a computer application or computer-aided design (CAD) component. Furthermore, each project is paired with a freshman course from the department of Humanities and Social Science (HSS) where the faculty involved advises the students on the preparation of project reports and the dynamics of oral presentation, the latter

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Table 1. The departments and faculty involved with the FE pilot course for the 1996 Fall

Section	Project	Department	Professor
FE-101-007	Lawn Sprinkler	M.E.	K. A. Narh, H. Surjanhata
paired with		I.M.E.	P. Ranky
HSS-101-003		Comp. Appl.	G. Milano
		HUM	R. Friedman
FE-101-103	Emergency Medical Service Field	E.C.E.	M. Sosnowski, J. Strano
paired with	Radio	BME	S. Reisman
HSS-101-019		HUM	D. Simmons
FE-019	Floop Disk Drive	M.E.	K. A. Narh, H. Surjanhata
paired with		E.C.E.	M. Sosnowski, J. Strano
HSS-101-025		Comp. Appl.	H. Assadipour
		HUM	R. Friedman
FE-101-023	Waste Treatment Facility	ChE	A. Perna, D. Hanesian
paired with		C.E.	G. Golub
HSS-101-005		E.C.E.	H-N Hsien
		Comp. Appl.	H. Assadipour
		HUM.	D. Power

being one of the many components of the curriculum. About 16 to 20 students work on each project with faculty from the various Departments acting as advisors. In this respect, there is no formal teaching in the conventional sense and no formal examination. Instead, the professors on the project act as facilatators. The truth, however, is that each professor introduces the students to his or her area of specialization by an indirect route, via the various components of the project in question. There were a total of nine departments involved in the pilot course, seven of these falling under the umbrella of Newark College of Engineering (NCE). The eight NCE departments involved are: Department of Biomedical Engineering (BME), Department of Chemical Engineering, Chemistry and Environmental Science (ChE, Chem. & Envirn Sc), Department of Civil and Environmental Engineering (CEE), Department of Electrical and Computer Engineering (ECE), Department of Electrical Engineering (EE), Department of Industrial and Manufacturing Engineering (IME) and Department of Mechanical Engineering (ME). For each project, the students are divided into teams of between 4 and 5 students per team. The course numbers, the titles of the four projects, the Departments and faculty involved in the Fall 1996 semester are shown in Table 1.

COURSE OBJECTIVES

As seen from Table 1, the Mechanical Engineering department was involved with two of the four projects. The main objectives of the course can be summarized as follows:

- to introduce the freshman engineering student to many aspects of engineering as an entire unit working together, with emphasis on the concept of teamwork in engineering research projects;
- to introduce the student to the computer-aided design tools available at NJIT which can be used not only to build models of the product to be manufactured but also for diagnostic analysis in order to solve potential manufacturing problems;
- to develop communication skills for team activities;
- to provide formal instruction on technical report writing and oral presentation, and have them practice and develop those skills.

The two projects, 'Lawn Sprinkler' and '3.5-inch Floppy Disk Drive' were chosen because they have the potential of incorporating all the concepts outlined above. Because of the similarities in the mechanical engineering components of these projects, only one project, the lawn sprinkler will be described in detail; any substantial differences that appeared between the two projects will be pointed out.

DESCRIPTION OF PROJECTS

The Lawn Sprinkler Project (FE-101-007)

The specific lawn sprinkler chosen for this project is the Nelson Rainshower 40 shown in Fig. 1. The sprinkler is used to sprinkle water on a lawn using a dial mechanism. The dial mechanisms on the sprinkler can be adjusted to oscillate a spray tube according to the selected pattern of coverage. Thus, the pattern of coverage can be controlled. The drive mechanism for the sprinkler consists of a turbine connected directly to a system of spur gears. No extra source of power is needed because the turbine drive mechanism is driven by water pressure. As the water enters the sprinkler, it goes through a nozzle directed to the turbine blades, drives a turbine at high speed, and enters a spray tube. The speed of turbine is then reduced by a spur gear system that drives a heart shaped cam at low speed. The cam moves the crank slot mechanism that oscillates the spray tube slowly. More than 90% of this particular lawn sprinkler is made of plastics, with the only metal component being the spray tube and the screws holding the various components. Most of the plastic

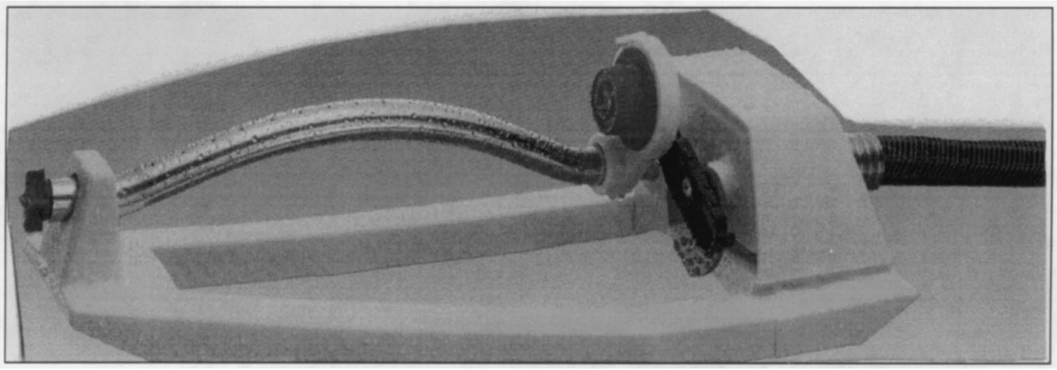

Fig. 1. Nelson Rainshower® 40 lawn sprinkler. Courtesy of L. R. Nelson Corporation.

components were injection molded; the final product was, presumably melt (spin) welded.

The 3.5-inch Floppy Disk Drive Project (FE 101-019)

The floppy disk drive has read/write capability, and uses electromagnetism to write or store programs and data. Basically, it is used to transfer information from a 3.5-inch diskette to the central processing unit (CPU) of a computer and vice versa. The media located inside the diskette is coated with a magnetic material that can record data. The read/write heads, which are tiny electromagnets, use magnetic pulses to change the polarity of metallic particles embedded in the disk's coating. The heads convert electric code signals from the computer into magnetic codes recorded on the surface of the disk; the drive then reverses this process to read the disk. A disk drive contains two small electric motors – a spindle motor to spin the disk at high speed and a stepper motor to move the magnetic read/write heads radially across the diskette's surface. When the computer system needs to access data on the diskette, the read/write heads are stepped by signals generated by the computer system's floppy controller. The floppy drive has about eight major components composed of plastics and metals. These include the main frame, the circuit board, the spin motor, the stepper motor, screw type shaft, read/write heads, the clamping mechanism, the front panel and door. The chassis, made of die cast aluminum, is the main frame on which all other components are mounted. A thermoset plastic material and conductive metals compose most of the circuit board. The screw-type shaft connected to the stepper motor is made of bronze. The front panel and door are made of plastic material. A torsion-spring-operated lever opens and shuts the shutter of the diskette enabling data to be accessed.

PROJECT OBJECTIVES

In order to fulfill the curriculum requirements for this course, the following project objectives were set out:

- Students should understand the dynamics of the team approach to the design and manufacture of the product.
- They should also understand the mechanisms involved in the operation of a lawn sprinkler system or floppy disk drive.
- They would learn about the multidisciplinary nature of the components of the products they are working with. In order to achieve this, they were required to disassemble their product, analyze it for design, function and choice of materials.
- They were expected to propose a design improvement with consideration of materials, environmental impact and manufacturing process for the product. In this regard, students would also be learning, indirectly, the fundamentals of *reverse engineering.*
- Students were expected to carry out CAD drawings of some of the product components, such as the spur gear of the lawn sprinkler or the front panel of the floppy disk drive.
- Analyses using mathematical software such as MathCAD [1] of gear dimensions and ratios (spring functions for those working with floppy disk drive) were to be carried out.
- The manufacturability of the part so designed was to be assessed through the use of a computer aided engineering (CAE) software. This last part of the project was limited to mold cavity filling analysis for the plastic component [2].

In order to achieve all these objectives and at the same time insure that the work load was not too much for these students, a well structured course syllabus was developed, which incorporates homework assignments to act as immediate feedback from the students. The syllabus for the lawn sprinkler project is shown in Table 2. The syllabus for the Floppy Disk Drive project was similar, as far as the mechanical engineering component is concerned, except in some specifics. For example, whereas students working on the lawn sprinkler project were introduced to gear types and arrangements (Table 2) in order to derive the necessary expressions for MathCAD calculations, those working on the floppy disk drive project were

Table 2. The course content for the lawn sprinkler project

Week	Topics
1	Introduction of TEAM ADVISORS Course Objectives, Description of Project (**M.E./I.M.E.**), and **I.M.E.** takes over.
2	**I.M.E.**: Conceptual Design Considerations & Modeling – Quality assurance, product quality, ethics, and Social impact.
3	**I.M.E.**: Details from professor
4	**I.M.E.**: Details from professor. Assignment: #1 (**I.M.E.**)
5	**M.E.**: Product Description and Function – Isometric sketching of the Product and component parts. A step-by-step instruction on how to sketch isometric view of the product. Each student is expected to participate.
6	**M.E.**: Disassembling of Product – Taking Measurement of Component Parts using dial calipers: A brief review of the functions of a dial caliper; types of calipers; Reverse Engineering: disassemble of the product and Itemization of Product Components; Detail measurement of component parts, with tolerances etc. Assignment #2: Group Report.
7	**M.E.**: Introduction to gear types and arrangements; gear terminology/nomenclature; gear systems as transmission of power; gear ratio based on input/output speed; Expressions for Mathcad Calculations. Assignment #3: Individual Effort on Mathcad Calculations.
8	**M.E.**: Materials and Processes – Materials for Engineering; Types of Materials: Metals, Ceramics and Glasses, Polymers, Composites, Semiconductors: Materials Processing (an overview of processes used to produce materials listed above). Introduction to Plastic Materials.
9	**M.E.**: Plastic Parts Manufacture – A Brief Description of Plastics Processing Techniques; Visit to Plastics Processing Lab. and the Factory Floor. Materials Selection: Engineering Design Parameters used in Materials for the Lawn Sprinkler: Plastic gears as opposed to metal gears. Assignment #4: Group Report
10	**M.E.**: Introduction to C-MOLD^{TM} – Getting acquainted with C-MOLD^{TM}. Preparing Pro/Engineer Model for Exporting to C-MOLD^{TM}: FEM Files.
11	**M.E.**: Introduction to Plastics Moldability Analysis – C-MOLD^{TM} Simulation of Mold Cavity Filling in Injection Molding (Filling EZ).
12	**I.M.E.**: Processes/manufacturing System, IE layout.
13	**M.E./I.M.E.**: Integration Session. Brief review of what is needed in the Final Report.
14	Final Report & Oral Presentations. Final Report to precede Presentation in order that students receive feedback from faculty on Final Report.

introduced to different types of springs and their functions for the purpose of obtaining the necessary MathCAD expressions. Of course, in the latter case, the student was also introduced to specific application of a spring in the design of a floppy disk drive. In this particular case, not only was the spring used to exert forces and torques but also as an energy storage mechanism for the front door of the floppy disk drive, shutter opener, and diskette clamping mechanism.

HOMEWORK ASSIGNMENTS

The homework assignments were based almost entirely on the topics discussed in class. Assignments consist of either a group mini report or an individual effort. As an example of a mini group report each team was asked to write a short report, using a word processor, to describe how the product for the project works – including a description of the materials used in the product. The report must be organized to include a title page, an abstract, a three-dimensional (free-hand) sketch of the product, a discussion of the function of each component part, and suggestions on any design improvements. On the other hand, assignments developed to evaluate the grasp of an individual student on a particular issue discussed during the class session, might, for example, require the students to perform simple mathematical calculations, plot graphs, with MathCAD – using the measurements taken in class.

STUDENT LEARNING OUTCOMES

In this section, some of the topics in Table 2 are discussed in order to give the reader an overview of this novel approach to freshman engineering instruction.

Disassembling of product and sketching the component parts – reverse engineering

In order to speed the disassembly process, a partial disassembly of the products was made before the session began. For instance, for the sprinkler project, a cut-out of the box which houses the turbine and the gear system was made, thereby exposing the gear train. Similar partial disassembly was made for the floppy disk drive.

The session began with the advisor reviewing the functions of the product. This was followed by a step-by-step instruction on how to free-hand sketch the isometric view of the product. Each student was expected to participate, i.e. each student must follow the instructor and sketch the product manually. Terminology associated with engineering drawing was also reviewed during the course of this exercise. This exercise was followed by a brief review of the materials used in the manufacture of the particular product chosen for the project.

The sprinkler gear assembly was then disassembled by each team, by removing the main screw holding the gear assemble to the turbine. This was followed by itemization of the component parts. The session ended with a brief overview of how measurements of small components can be carried out using a dial caliper. The homework assignment for this part of the project is a mini group report with portions designed to reward individual efforts. In this assignment, the three-dimensional sketch of the lawn sprinkler is graded on an individual basis whereas the main report without the isometric sketch is graded as a group effort.

Gear nomenclature, terminology and expressions for MathCAD

Different types and functions of gears and the associated gear terminology/nomenclature were reviewed. In particular, the use of gear systems as transmission of power was reviewed, followed by some basic expressions for gear dimensions, ratios and their relationship with input/output speed. These are all necessary for designing a gear system.

In contrast, students working on the floppy disk drive project learned about different types of springs (including special springs), their functions and the terminology associated with springs, as these apply in the design of a floppy disk drive. The screw type shaft as a mechanism for positioning the read/write heads in the floppy drive was also reviewed. Because MathCAD instruction was running parallel with the projects, it was possible to introduce a few mathematical expressions so that students could test their knowledge on the use of MathCAD.

Materials and processes

The type of materials used for engineering products in general were reviewed under these topics: metals, ceramics and glasses, polymers, composites, semiconductors. This was followed by an overview of processes used to produce the materials listed above. In order to underscore the role of plastics in the two projects, students were introduced to the range of plastic materials available and the fabrication methods. The Materials Selection procedure was confined to plastics products with injection molding being the selected manufacturing process.

Use of CAD in the projects

The hand-drawn orthographic view was used as a basis of the CAD process using Pro/ENGINEER CAD software. The steps taken to generate the CAD model are basically the same for each project. The steps taken were summarized in a step-by-step manual given to the students.

Computer simulation of injection molding process

At this stage, the students have made sufficient progress in the exercises, so the subject of productivity solution, a common industry practice for troubleshooting the manufacturing process, was introduced. To this end, a step-by-step manual was prepared which enabled the students not only to export their Pro/ENGINEER solid models into C-MOLD^{TM} module for mold cavity filling analysis, but also to carry out the simulation process with very little assistance from the professor. The simulation exercise was limited to the first level of plastics manufacturing process, the so-called Filling-EZ. This consists of accessing the database of C-MOLD^{TM} for the properties of the polymeric material used in the manufacture of the product for the project. The material properties

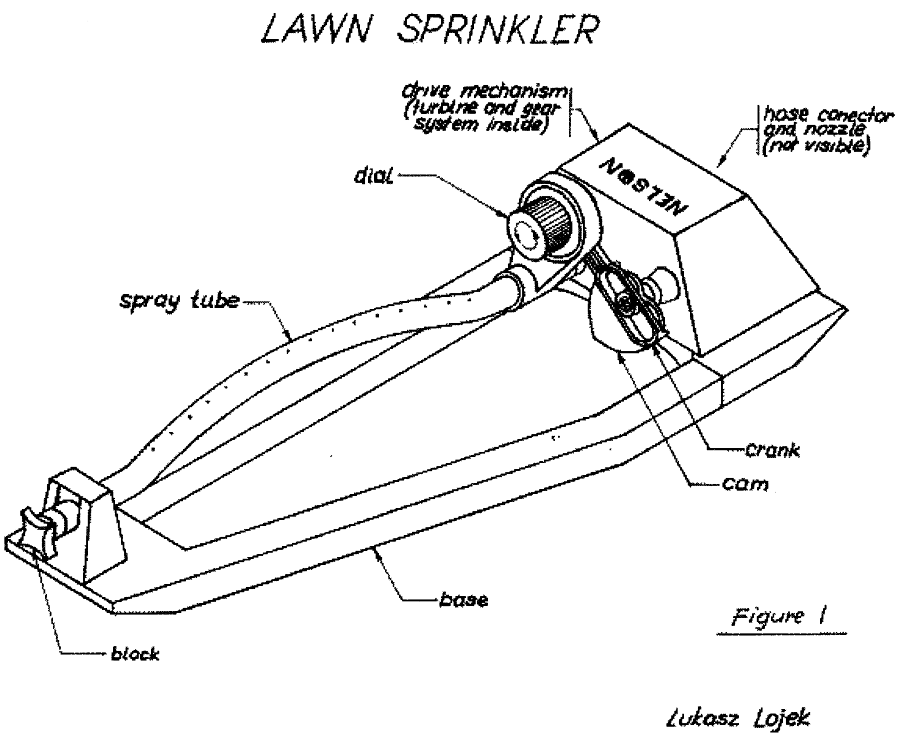

Fig. 2. Isometric sketching of lawn sprinkler – students' drawing.

Table 3. The grading scheme

Course Component	Grades Allocation (%)
Final Project Report	30
Oral Presentation	30
Design Assignments	20
Software Applications	20
Grade Distribution for Project Report:	
Table of Contents	5
Abstract	10
Introduction	20
Design Process	15
Software Applications	10
Conclusions	10
Recommendations	10
References &	5
Appendix	15

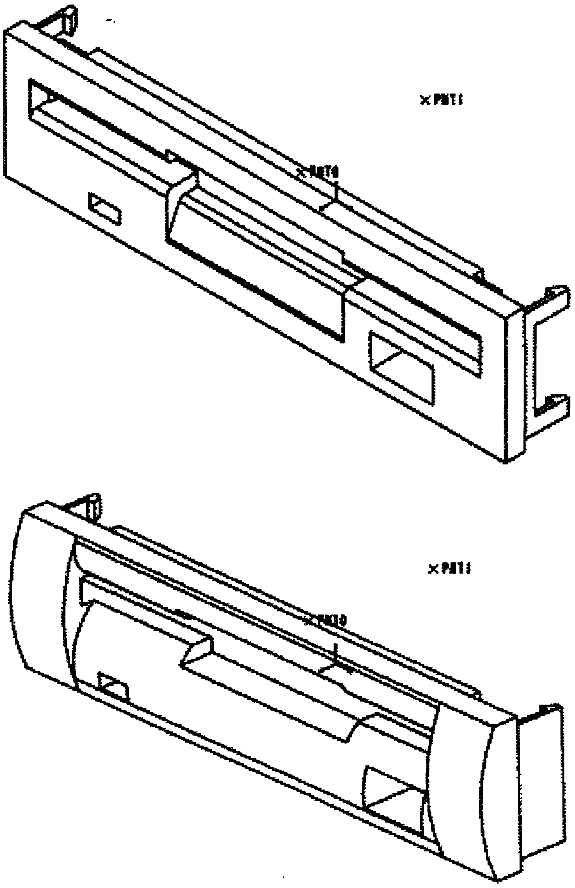

Fig. 3. Pro/ENGINEER® generated floppy drive front panel – students' models. PNT0 and PNT1 shown in the figures are runners for C-MOLD™ injection molding analysis. The lower model represents the team's design improvement of the panels.

were then used to simulate the *melt front advancement* in the mold cavity. Students also examined the presence of weld lines and their location in relation to the location of the runner (a runner is a channel that distributes the molten material into the cavity). Weld lines are potential sources of structural weakness in an injection molded part. They are formed, during the filling stage, when the melt front separates and recombines at some downstream stage. The presence of weld lines and/or air traps enabled the student to identify a potential manufacturing problem and to propose a possible solution such as relocating the gate (the gate is a narrow constriction that connects the runner to the mold cavity).

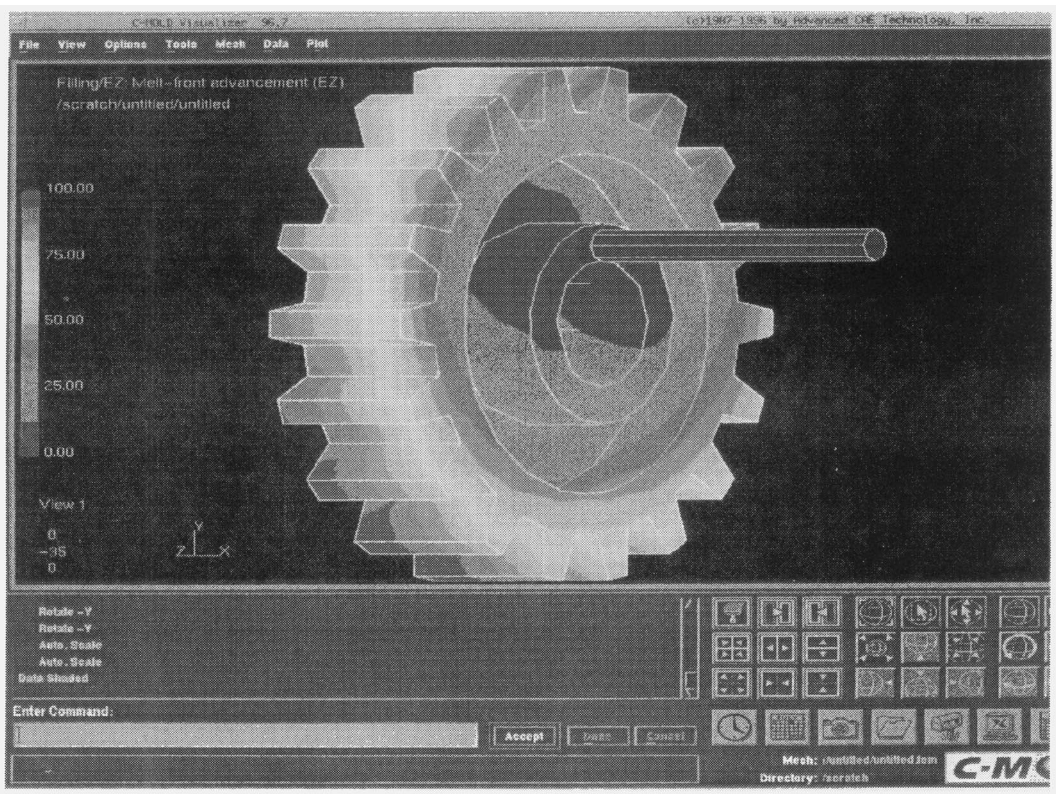

Fig. 4. Melt front advancement resulted from C-MOLDTM analysis - students' model analysis.

Table 4. A scanned sample of the assessment scheme for Oral Presentation prepared by the Department of Humanity and Social Science

NJIT/HSS Learning Outcomes **HSS Oral Presentation Review**

Team #/Student Names: ______________________ Rater's Name ______________

Please rate how well the team, as a whole, demonstrated the following knowledge, skills, and abilities throughout this oral presentation.

During this oral presentation, the team demonstrated the following knowledge, skills, and abilities:	Not at All	To a Limited Extent	To a Moderate Extent	To a Great Extent	To a Very Great Extent
Analytical Skills: Analyzed problems from different points of view and in a logical manner.	1	2	3	4	5
Communication Skills: Articulated their ideas clearly and concisely throughout the oral presentation.	1	2	3	4	5
Used a variety of persuasive strategies to influence your acceptance of their points of view.					
Creative Problem-solving: Suggested new approaches to solving problems.	1	2	3	4	5
Project Management: Demonstrated that they were able to set goals, prioritize tasks, and coordinate their efforts towards the final assignment	1	2	3	4	5
Research Skills: Uses outside sources of information found through such methods as the internet, hard-copy indexes and abstracts, articles, books, cd-rom, etc.	1	2	3	4	5
Self Learning: Went beyond requirements when completing this assignment.	1	2	3	4	5
Systems Thinking: Integrated knowledge from diverse sources to solve problems in integrated manner.	1	2	3	4	5
Teamwork: Showed evidence of cooperating with each other to plan and deliver this presentation.	1	2	3	4	5
Technical Competence: Demonstrated a basic knowledge of fundamental principles of communication including audience analysis, peer & instructor review, and the role of revision.	1	2	3	4	5
Demonstrated knowledge of a range of topics covered in the course reader including topics such as defining science, applying technology, practicing science, considering ethical dilemmas, and writing to construct science & technology.	1	2	3	4	5
Demonstrated an ability to use computer tools in the service of communication including the ability to create visuals for oral presentations.	1	2	3	4	5
Holistic Assessment: Overall, the team effectively presented their project findings and results.	1	2	3	4	5

Sample results from students' efforts

Figures 2, 3 and 4 illustrate some samples of the results from selected project reports. The sample results shown here represent about seven weeks (4.25 hours per week) team efforts by the students.

THE GRADING SCHEME

There was no formal examination for this course and the grade for the semester is a composite of grades from four main categories: oral presentation, final project report, homework assignments (including quizzes), and software applications. Table 3 summarizes the grading scheme for various components of the course. Table 3 also shows the distribution of grades for the final project report, based on a project report format previously reviewed with the students. The assessment for oral presentation was based on a format prepared by the Department of Humanity and Social Science, and reproduced in Table 4. Since the emphasis in this course was on team work, the rating of the presentation was based mainly on team effort.

Table 5. A scanned sample of the interview survey result.

NJIT Learning Outcomes
Pre-Interview Student Survey
Course Name ______________________________ Section # __________________
N = 13 17 students enrolled 76.5% responded

During this course I was provided with the opportunity to learn and practice the following skills: Rating Scale: 1 Not at All to 5 To a Very Great Extent	Average Response	Average Response from all students
Analyze problems from different points of view.	3.54	3.55
Apply logic in solving problems.	4.00	3.60
Read documents critically. Goes beyond merely summarizing documents and instead, read in order to pose informed questions.	3.23	3.20
In written presentations, articulate ideas clearly and concisely.	3.54	3.60
In oral presentations, articulate ideas clearly and concisely.	3.92	3.60
Use a variety of persuasive strategies in written and oral presentations.	3.77	3.20
Meet project milestones & deadlines.	3.92	3.80
Take corrective action based on feedback from others.	3.77	3.70
Maintain course materials (i.e. portfolios) in a professional manner.	3.69	3.53
Understand importance of learning what has already been done to solve a given problem.	3.69	3.60
Document sources of information.	3.54	3.20
Use outside sources of information found through such methods as the internet, hard-copy indexes and abstracts, articles, books, CD-ROM, etc.		
Demonstrate ability to learn independently.	3.77	3.90
Go beyond requirements when completing assignments.	3.92	3.00
Learn from mistakes.	4.23	3.90
Demonstrate an understanding as to how events interrelate with each other.	3.77	4.00
Integrate knowledge from diverse sources to solve problems in an integrated manner.	3.69	3.00
Take new information and effectively integrates with previous knowledge.	3.62	4.00
Share credit for success with others.	4.15	3.80
Cooperate with others.	4.15	4.10
Encourage participation among all team members.	4.31	4.00
Demonstrate a basic knowledge of fundamental principles of engineering and how various disciplines interact with each other	3.92	3.70
Demonstrate knowledge of a range of topics covered in the course including topics such as defining science, applying technology, practicing science, and considering ethical dilemmas.	3.77	3.60
Demonstrate an ability to use computer tools in the service of communication including a proficient level of word processing and the ability to create visuals for oral presentations.	4.00	3.90

COURSE EVALUATION METHODOLOGY

Four methods have been used to evaluate the impact of the FE pilot course on the students. These were:

(1) an interview survey of all the students participating in the pilot run,
(2) Team Developer™ survey,
(3) standard teacher evaluation
(4) project evaluation.

The evaluation procedures for three of the four schemes listed in (1) – (4) are controlled by the office of the Dean of Engineering with most of the methodology prepared by the department of Humanity and Social Science (HSS). The project reports were evaluated in accordance with guidelines given to the students by the team advisors, shown in Table 3. The project reports were regarded as strictly team effort and was evaluated as such. Each report was rated for both technical content and grammar. The distribution of grades for each section of the report is shown in Table 3. The evaluation procedures will now be described.

The interview survey

As part of the evaluation process, toward the end of the semester, students were interviewed. The purpose of this interview is to obtain the facts – directly from the students, what type of skills the students has developed or acquired by taking this course. The questions are structured in such a way so that they covered analytical, communication, project management, researching information, team works, science and math, and computer skills. Table 4 shows the listed items of the interview.

In summary, the outcome of this survey (see Table 5) indicates that the students were quite satisfied with what they learned, regarding the skills mentioned above. It is important to note that for all students Go beyond requirements was rated at the lowest point. This suggests that this is the area that needs to be strengthened by us as

Table 6. An example of scanned Team Developer™ survey results for the Lawn Sprinkler Project.

Team Developer Results Results for: Team: Sec. 7-2	Self	Team
ANALYTICAL THINKING	3.29	3.50
Demonstrate a basic knowledge of fundamental engineering principles as required	3.00	4.25
Anticipates problems and develops contingency plans	3.00	3.00
Recognizes interrelationships among problems and issues	3.00	3.50
Applies logic in solving problems	3.00	3.75
Scales down information to what is important	4.00	4.00
Translates academic theory to real practical applications	3.00	2.75
Demonstrates ethical awareness on how decisions can impact oneself, others and the e	4.00	3.25
COMMUNICATION	3.44	3.47
Listens attentively to others without interrupting	4.00	4.00
Articulates ideas clearly and concisely	3.00	3.75
Uses facts to get points across to others	3.00	3.25
Persuades others to adopt a particular point of view	4.00	3.25
Gives compelling reasons for ideas	3.00	3.25
Plans and delivers oral presentations effectively	4.00	4.50
Organizes written materials in a logical sequence to enhance reader's comprehension	4.00	2.75
Applies presentation tools effectively, i.e., create visuals for oral presentations	2.00	3.00
Demonstrates an ability to "think on one's feet"	4.00	3.50
CREATIVE PROBLEM-SOLVING	3.33	3.13
Challenges the way things are normally done	2.00	2.75
Improves on what has been done before	4.00	3.25
Generates many potential solutions to a given problem	3.00	3.25
Suggests new approaches to solving problems	4.00	3.25
Discourages others from rushing to conclusions without facts	4.00	3.00
Handles unknowns or open-ended questions effectively	3.00	3.25
PROJECT MANAGEMENT	3.55	3.14
Sets goals to accomplish tasks on time	3.00	2.75
Clarifies task requirements and expectations as needed	3.00	3.50
Creates action plans and timetables to complete assigned work	2.00	2.50
Meets project milestones & deadlines	5.00	3.50
Prioritizes tasks to ensure meeting project milestones	3.00	3.50
Takes corrective action based on feedback from others	4.00	3.50
Stays focused on the task during team meetings	4.00	3.50
Uses meeting time efficiently	4.00	2.75
Suggests ways to proceed during work sessions	4.00	2.75
RESEARCH SKILLS	2.75	3.06
Brings in information from "outside" sources to help make decisions	2.00	2.75
Uses computer-based resources effectively to acquire needed information	2.00	2.75
Seeks information on problem from multiple sources	3.00	2.75
Understands importance of learning what has already been done to solve a given problem	4.00	4.00
SELF LEARNING	3.00	3.25
Demonstrates ability to learn independently	3.00	3.50
Goes beyond requirements when completing assignments	3.00	2.50
Learns from mistakes	3.00	3.75
SYSTEMS THINKING	2.67	3.33
Demonstrates an understanding as to how events interrelate with each other	3.00	3.25
Integrates knowledge from diverse sources to solve problems	2.00	3.50
Takes new information and effectively integrates with previous knowledge	3.00	3.25
TEAMWORK	4.17	3.63
Helps reconcile differences of opinion among members	4.00	3.00
Shares credit for success with others	4.00	3.00
Cooperates with others	5.00	4.50
Encourages participation among all team members	5.00	3.75
Shares information with others	5.00	3.75
Contributes to the project's workload	5.00	3.75
Encourages ideas and opinions even when they differ from his/her own	3.00	3.75
Works towards solutions and compromises that are acceptable to all involved	4.00	3.50
Helps reconcile differences of opinion	4.00	3.00
Accepts criticism openly and non-defensively	4.00	4.25
Reinforces the contributions of others	4.00	3.50

Table 6. Continued

TECHNICAL COMPETENCE		
Demonstrates a basic knowledge of fundamental engineering principles as required	3.00	3.50
Incorporates principles of physical sciences and advanced mathematical into the solution	3.00	3.25
Uses a basic knowledge of social sciences and humanities in the formulation of problem	3.00	4.00
Shows awareness as to how various engineering disciplines complement each other	2.00	3.00
Uses appropriate quality tools and methods to solve problems	3.00	3.25
Uses computer tools such as Pro Engineer effectively	2.00	2.75
Demonstrates an awareness of how what is learned in the classroom applies to industry	3.00	3.25

educators. Also it seems the students enjoyed working together as a team, as shown in the results of this survey. This is good news since success in the real working world is based on a team work.

Team Developer™ Survey

In the Team Developer™ survey, each student was given a 3.5-inch floppy disk with survey questions which require the student to rate him/herself and his/her team members on their project. This floppy disk was distributed toward the end of the semester. The disk was created by Assessment Alternatives, Inc. of Florham Park New Jersey. This survey is confidential in that a student is not only evaluating his or her performance but also 'peer reviewing' the team members. An example of Team Developer™ survey results for the lawn sprinkler project from the student is shown in Table 6. In this table, the number recorded against the topic in the row is the average of the student's rating. The rating is from 1 to 5, 5 being the highest. Sample results from the Team Developer™ survey for four teams on the lawn sprinkler project are shown plotted in Fig. 5. The objective is to check if a pattern will emerge from the survey results. The data in Fig. 5 for each team member is fitted with a linear regression. As seen, no particular pattern has emerged from the survey, nevertheless, the near-linear relationship between self(s) and team evaluation in some cases can assist advisor in resolving team conflicts. For example, team member s_1 from Team 2 appears to have rated his contribution to the team effort much higher than the rest of the other members (downward trend in the regression line indicate self rating is higher than team rating in most cases). The case scenario could arise where s_1 complains of the other members not contributing much to the project. In such a case, the 'built-in check' on individual efforts will come into play. Is he exaggerating his contribution, simply finding an excuse for a poor performance, or has he got a case? Using his initiative (of course) together with surveys such as these, and the data on individual effort, problems of this nature can be resolved quickly by the team faculty advisor. Regarding the other two methods used for course evaluations, instructor evaluation by the student and project evaluation by the instructor, suffice to say that the former used a standard NJIT format while the latter has already been discussed in section VIII.

DISCUSSION AND CONCLUSIONS

The impact of the mechanical engineering projects within the entire freshman engineering

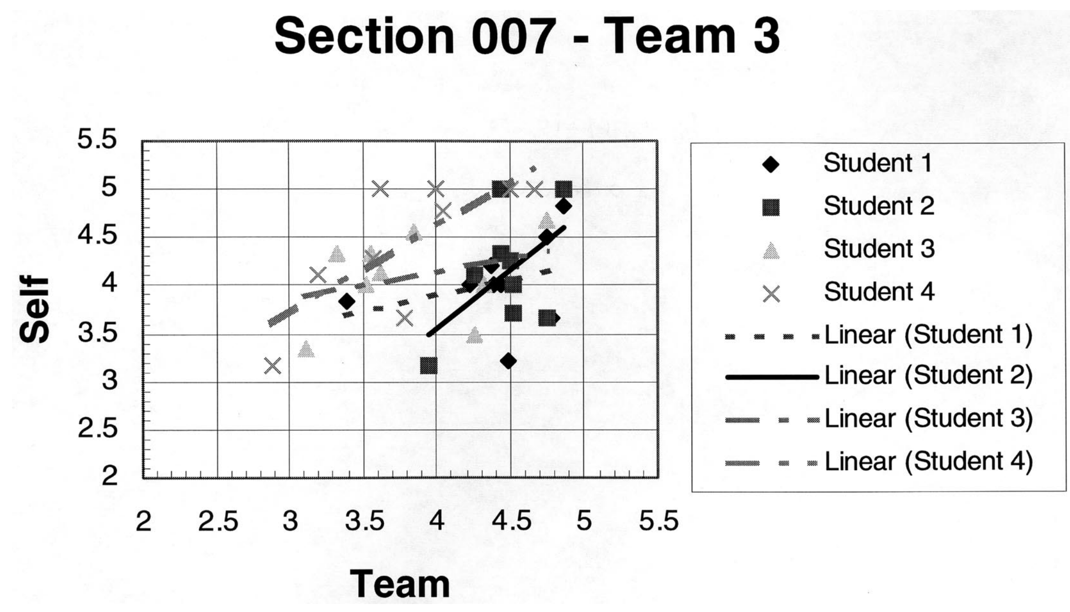

Fig. 5. Plots of Team Developer™ survey results for one team on the lawn sprinkler project.

curriculum is difficult to evaluate since only a limited number of students participated. However, all the students who participated in the two project-based course modules have successfully used all the software they were introduced to in 1) writing a technical report, 2) drawing 3-D models of the selected component parts of their product, and 3) performing simple mathematical calculations, and plotting graphs.

Judging solely from the students' sample results shown in this paper and the student feedback (not reproduced in this report), and bearing in mind that most of these students had no prior exposure to any engineering training, it appears the mechanical engineering projects have achieved their initial goals of introducing the freshman engineering student to the use of CAD and design software in early stages of their engineering training.

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Dr. Kwabena A. Narh is an Associate Professor in the Mechanical Engineering Department at New Jersey Institute of Technology (NJIT). He joined NJIT in 1994 from Cornell University where he had been a postdoctoral research associate for two years. He received his masters and Ph.D. degrees from University of Bristol, U.K.; and his BS degree from University of Ghana. His area of specialization is Plastics Engineering. His teaching and research activities focus on the use of combined parametric and experimental methodologies to predict the relationships between properties of plastic products and process parameters. Dr. Narh has published more than 50 journal and conference papers covering a wide range of topics in Polymer Physics and Plastics Engineering. He is a member of several professional societies, including American Society of Mechanical Engineers, Americal Physical Society, Society of Plastics Engineers, Sigma XI and ASEE. He currently serves as the chairperson of SPE Polymer Analysis Division's Award Committee, and the division's Technical Program Chair for the 2001 annual technical conference. (Email: narh@njit.edu).

Dr. Herli Surjanhata is a lecturer in the Department of Mechanical Engineering at New Jersey Institute of Technology (NJIT). He is also an associate member of ASME. He holds a B.Sc. degree from Trisakti University (Indonesia), M.Sc. and Ph.D. degrees from NJIT, all in Mechanical Engineering. His teaching and research interests include CAD/CAM, finite elements, mechanical design, graphics, and design optimization. (E-mail: surjanhata@admin.njit.edu).