Improving Freshman Retention Through an Introduction to Engineering Design Course

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Abstract

A freshman engineering design course at California State University, Chico is described. The primary motivation for creating the course was to encourage students to continue their study of Mechanical Engineering. The course appears to have significantly decreased the attrition of Mechanical Engineering majors. To date 79% of the freshman Mechanical Engineering majors who have taken the course have become sophomore Mechanical Engineering majors and 21% have changed majors or left California State University, Chico before becoming sophomores. The history leading to the design of the course as well as the course's objectives, structure and requirements are described. The course involves teams of students designing, building and testing devices that participate in competitions. Examples of these projects are discussed.

The Problem

Following increasing enrollment in Mechanical Engineering (ME) at California State University, Chico (CSUC) in the early 1980s, the enrollment began to decline (see Fig. 1). This decline was perceived by the faculty to be a problem. The one-year attrition rate of fall first-time freshmen ME majors at CSUC from 1973 to 1990 was 50%, i.e., 50% of fall first-time freshmen who had declared their major to be ME changed their major or were not at CSUC one year later. The solution discussed here was intended to increase enrollment by reducing attrition.

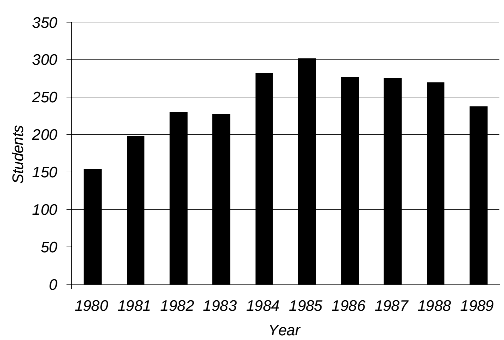

Figure 1: Fall enrollment in Mechanical Engineering at CSUC

Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exposition

A Solution

In the late 1980s Mechanical Engineering Design I (ME138) was perhaps the best liked ME course at CSUC. The course had two distinct parts: three 50-minute lectures per week on machine design and a three-hour per week laboratory in which groups of students designed, built and tested computer controlled “robots” and entered them in a class competition. It was evident that the laboratory project was the big draw. Students not in the class talked about the competition and came to watch it. Students in the course asked if they could take the lab portion again or another course similar to it. After completing the course students came to observe the competitions of succeeding classes. While in principle the intent of the laboratory project was to apply and reinforce the knowledge presented in the lectures, in reality that infrequently occurred. The lab and lecture portions were at best loosely related. The analytical skills discussed in the lectures were rarely used in the design of the robots.

Based on these observations, and the perceived need to increase beginning students’ motivation to continue studying ME, an experimental freshman course was offered in fall 1990 called Introduction to Engineering Design. The basis of the course was the ME138 lab project. Because the audience was assumed to have no computer programming experience, the experimental course was assigned 2 semester units and met four hours per week. This provided time to teach more computer programming skills than was done in the ME138 lab. The assumption was that freshman could learn just as much about design as the juniors were learning in the ME138 lab and while doing so would be motivate to continue on in engineering despite, in many cases, difficulty with the heavy dose of math and science that dominates the first two years of the curriculum.

This approach has similarities to the notion in industrial psychology of the “realistic job preview”. The premise is that job turnover is reduced if the job applicant can be given a realistic view of what the applicant will actually do on the job. One aspect of this is that some decisions “require a person to experience short-term discomfort in order to satisfy a long-term goal.”[1] Wanous cites 12 studies testing the efficacy of a realistic job preview at increasing an employee’s survival on the job. In nine of the studies, those employees participating in a realistic job preview persisted on the job longer than those who had not participated in a realistic job preview. In three of the studies there was no difference between the experimental and control groups, but in most of these the job terminations were non-voluntary.

The ME faculty judged the experimental course to be sufficiently worthwhile that, beginning in fall 1993, the course (ME38, Introduction to Engineering Design) became a degree requirement.

The Details

The objectives of ME38 expanded somewhat from the initial conception to become:

1. To motivate the students to continue study of engineering
2. For the students to learn a process for designing mechanical systems
3. To give the students opportunities to be creative
4. To encourage teamwork

5. To introduce the students to the concept of using a computer to control an electro-mechanical system
6. To strengthen the students' written, oral and graphical communication skills

The motivation for initiating the course remains its primary objective, to motivate students to continue studying engineering by providing a view of what mechanical engineers do and a reason why the early abundance of math and science and dearth of application should not discourage them. CSUC ME majors seem to be very excited about being designers and handling hardware and less excited about the science and math necessary to accomplish sophisticated designs.

Engineers do many things, but at the heart of engineering is the notion that an engineer is a designer, one who formulates plans to solve problems. Thus, an objective of the course is to provide a foundation for most all of the ME curriculum at CSUC by defining a structure for the design process. Design involves creativity and while one would like to "teach" designers how to be creative, this course does not do that because the instructor does not know how to "teach" it. As an alternative, opportunities are provided and students are encouraged to be creative. The hope is that as a consequence the students will increase their creative abilities. Furthermore, industry wants university graduates to be proficient at working with others; consequently, the course is strongly teamwork oriented.

Teaching of engineering facts is basic to the purpose of most engineering courses. In this case, however, it was not a factor in the original motivation for the course. Irregardless, the objective of introducing the students to the concept of using a computer to control an electro-mechanical system seeks to impart specific knowledge of the engineering topic of computer programming and the notion of how a digital computer can be used as a hardware element in a mechanical device. This is perhaps the single "conventional type" objective of ME38.

Facility at communication is probably the most important skill any college graduate can attain. Furthermore, excellent communication skills cannot be acquired solely from courses in written, verbal and graphical communication. Practice is needed as often as possible. Consequently, when appropriate it is desirable that all courses reinforce communication skills. While practice at writing, speaking and drawing is not appropriate in many engineering courses, it is natural in a course such as this.

The course is divided into four parts:

1. Introduction to the design process (2 weeks)
2. Design project 1 (2 1/2 weeks)
3. Computer control of motors (2 1/2 weeks)
4. Design project 2 (9 weeks)

During the introductory part, one paradigm for a procedure for designing things is discussed and various classroom exercises are used to reinforce the concepts presented. The paradigm discussed consists of six steps:

1. Defining the problem – specifying what the design must do
2. Conceptualization – generating and evaluating concepts for the solution of the problem
3. Design of details – fleshing out a concept into a complete solution of the problem
4. Fabrication – building the solution
5. Testing – verifying the solution solves the problem
6. Communication of solution – presenting the solution to the client

The first design project (Project 1) requires a team (usually of two students) to design, build and test a simple device constructed from simple materials. Examples of materials used are foam core board, masonite, wooden dowels, rubber bands, paper clips, thumb tacks, nails, washers, soda straws, colored construction paper, hot-melt glue, white glue, and nylon string. The project culminates with a competition. The objective is to apply what was learned in Part 1 of the course to a specific design problem. To encourage creativity, projects are rarely reused.

After Project 1 is completed, the course enters its third part, which prepares the students for Project 2. Project 2 always involves a device actuated by small electric motors which are powered by computer controlled power supplies. The computer language used is Microsoft QuickBasic. Upon entering the class, all students have used a computer, but their skills are quite varied. Some have only played games and perhaps used the Internet, while others can write programs in several computer languages. The range of expertise is considerable. The assumption made in ME38 is that all have used a computer to do something, but none have any programming knowledge. With this as a starting point, students are taught to write an elementary program to control two power supplies. This introduction to programming becomes the foundation upon which later courses build. ME38 is not intended to teach programming in much detail, but rather to teach what is necessary to allow students to write their own programs to control the power supplies which will be used in Project 2.

Once all students can write a simple program to control two power supplies, Project 2 is assigned. The remainder of the semester is primarily spent on Project 2. During that time an introduction to working drawings is presented. One of the requirements of Project 2 is an assembly drawing of the device. The format is informal in the sense that it can be drawn freehand and only approximately to scale, i.e. a sketch, but it needs to use engineering assembly drawing conventions.

Examples of the first project used in the course are listed in Table 1. In each a device is to be designed and built to accomplish a well-defined task. None of these involve a computer controlling motors. In most projects, a trigger that activates the autonomous device must be designed into it. Examples of Project 2 are listed in Table 2. A complete printed problem statement for each was given to the students when it was first presented. All requirements were in writing and rarely were they amended after the original distribution. When they were amended, it was done in the form of a written memo. For a copy of any project statement, contact the author (rroth@csuchico.edu).

Table 1: Examples of Project 1

Semester	Project Title	Brief Description
F90	UPS Express	A device moves a "package" (simulated by a wooden cube) from inside a circle to outside of a concentric circle.
F91	Ping-Pong Tetrathlon	Teams of four create a device to simulate the playing of four Olympic events using a ping-pong ball to represent the progression of play. (This project is a copy of a similar project obtained from an ASEE Workshop[2].)
S92	Stick Jump	A device moves itself over a horizontal 36 in long dowel supported 11 in above the floor.
F94	Stick Climb	A device climbs a 37 in long vertical 3/8 in dowel as fast as it can.
S95	The Rectangle	A device is to move all (or part) of itself through a vertical 3 ft x 4 ft rectangular frame in less than 15 s while maximizing the weight moved.
F95	The Tightrope	The device moves itself 6 ft along a taut horizontal string stretched 4 ft above the floor.
S96	A Distance Gauge	A mark on the device is to be moved 6 ft in a prescribed direction when triggered.
F96	Let's Play Golf	A golf ball simulated by a 1.2 in diameter x 0.75 in long cylinder is moved from "the tee" to each of three "holes" one and two feet away.
S97	The Ring Slide	A taut horizontal cord supports a ring that can slide freely on it. The device moves the ring from one mark on the cord to a second mark one foot away and then to a third mark two feet away.
F97	Shooting Hoops	A "basket" is to be made using a ping-pong ball from behind a "three-point line" on a 4 ft x 8 ft basketball court.
S98	Budging Blocks	Eight wooden blocks are to be removed from a 2 ft diameter circle.
F98	Walking Through the Wood	A "hiker" simulated by a tennis ball is to be moved on a prescribed path through a simulated forest.
S99	Soccer Shootout	A soccer goal is to be scored using a ping-pong ball on a simulated soccer field.
F99	Trouble in Turkey	Simulated earthquake devastated buildings are to be cleared from a simulated square block of Istanbul.
S00	The Harvest	Six model trees are to be removed from a 0.6 m diameter circle.
F00	Ping-Pong Tetrathlon	Repeat of F91 project.

Table 2: Examples of Project 2

Semester	Project Title	Brief Description
F90	North Valley Nuts	Two "nut pickers" compete to pick the most "nuts" (simulated by ping-pong balls held on by Velcro) off of "trees" made of wooden dowels.
F91	Let's Go Fishing	Two "fishing systems" compete to catch the most "fish" (rubber lures) and transport them back to "port" (a specific region on a 4 ft x 12 ft table that simulates an ocean with waves).
S92	The Non-Presidential Race	A race between two devices to traverse an obstacle course on a 10 ft x 10 ft table which includes a variety of alternate routes through water, sand, hills, spikes, walls and bumps.
F94	Sound the Alarm	Five audible alarms are connected to five switches place in various positions on an 8 ft x 8 ft table. Devices compete to determine which can trigger three alarms first.
S95	Tree Climber	Two devices race to climb two trees simulated by two vertical steel rods with smaller steel rod branches. (There were three projects in S95. This was actually the third project, but had the characteristics of a typical Project 2.)
F95	The Cord Maze	Several taut cords supported at various heights and in various directions form a cord maze. Two devices race to move themselves from one marked section of one cord to another marked section of another cord.
S96	The Wall Climb	A climbing device scales a 3 ft wall.
F96	Climbing Mt. Vesuvius	Two "mountain climbers" race from their base camps at the foot of a (non-erupting) volcano 7 ft in diameter x 2 ft high to the caldera at the top.
S97	Mining Nutty Nodules	Many ¼ in nuts are scattered on an 8 ft x 8 ft table that simulates the ocean. Two "mining devices" race to collect the most nutty nodules.
F97	Ping-Pong Basketball	Two "basketball players" play full-court basketball simulated by a ping-pong ball on a 4 ft x 8 ft basketball court.
S98	Collecting Blocks	Two devices are to collect various weight and shape blocks from a table and deposit them in two hoppers.
F98	Shooting Ducks	"Duck hunters" are to knock down "flying ducks" simulated by ping-pong balls suspended by Velcro from a randomly moving "clothes line".
S99	The Leaning Tower of Chico	A model of an actual leaning tower on a theatre in Chico is to be straightened.
F99	Trouble in Turkey: Rebuilding in the Aftermath	"Building repairers" are to rebuild buildings (simulated by stacking blocks) on a 1.2 m x 2.4 m table that simulates a destroyed portion of Istanbul.
S00	Reforestation	Model trees are to be "planted" in holes on a 1.2 m x 2.4 m table that simulates a forest.
F00	Soccer – Chico Style	Two "soccer players" compete to score a goal on a 1.2 m x 4.8 m soccer field table.

A small fabrication facility equipped with simple tools is dedicated for the use of students in ME38. It has relatively safe power tools (a drill press, scroll saw and belt sander), a variety of hand tools (hot melt glue guns, clamps, vises, utility knives, exacto knives, metal meter sticks, squares, compasses, saws, drill, files, pliers, wire cutters, etc.), soldering irons, work benches and large individual student team storage lockers.

Sprinkled throughout the course are various ungraded classroom exercises to emphasize creativity, teamwork and communication skills. The videos **To Engineer Is Human**[3] and **21st Century Jet**[4] are commonly shown and discussed. Grading is based on the six factors listed in Table 3.

Table 3: Basis for course grade

Factor	Percent of Course Grade	Description
Graded exercises	15%	5 or 6 short assignments (some done in class, others not) designed to reinforce something discussed in class
Creativity essay	15%	Essay on **A Whack on the Side of The Head**[5]
Project 1	15%	Performance in competition, quality of hardware and a design logbook
Analysis of Project 1	5%	A written analysis focusing on the process used to design Project 1
Project 2	40%	Performance in competition, quality of hardware and software, 3 oral design reviews, assembly drawing and design logbook
Analysis of Project 2	10%	An oral presentation focusing on the process used to design Project 2

Results

A cohort of 160 freshmen ME majors have taken ME38 since it became a ME requirement in fall 1993. Table 4 tracks the cohort. Omitting from the cohort those who are still freshmen, 79% have gone on to become sophomores majoring in ME, i.e., a retention rate of 79% and an attrition rate is 21%.

Table 4: Status of 160 freshman Mechanical Engineering majors who took ME38

Status	Number of Students	Percentage of Cohort
Became sophomore* ME major	109	68
Changed major before becoming sophomore*	13	8
Left CSUC as ME major before becoming sophomore*	16	10
Currently freshmen ME major	22	14

*Completed more than 29 semester units

The CSUC Office of Institutional Research has reported on the persistence rate of fall semester first-time freshmen majoring in ME at CSUC. Its report defines persistence rate as the percentage of fall first-time freshmen in a major who the following fall remain enrolled as CSUC in the same major. Between 1973 and 1989 (prior to the creation of the experimental version of ME38) the persistence rate for ME was 50%.[6]

Conclusion

The retention rate of 79% for freshmen ME majors taking ME38 suggests that ME38 may have significantly reduced the attrition from ME at CSUC.

Since ME38 is a required course for ME majors and nearly all take it as a freshman, no simultaneous control group of CSUC ME majors exists. The persistence of 50% of fall first-time freshmen in ME prior to the first offering of the experimental course in fall 1990 suggests that the course may have a positive effect on reducing attrition.

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