Session 1566

Improving Retention of Undergraduate Students in Engineering through Freshman Courses

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Abstract

Demand for competent engineers has increased significantly in recent years and as the local availability decreases, corporations have increased efforts to import engineering graduates from abroad. Achieving a significant increase in the number of U.S. graduates in science, mathematics and engineering is a complex problem that requires the participation of many parties.

This paper addresses the steps taken by the Mechanical Engineering Department at Alabama A&M University to improve retention rates of engineering freshman through two introductory courses in mechanical engineering. The focus of one course is the facilitation of the development of new engineering competencies. The authors have adapted/developed materials and examples from several sources for the introductory freshman course in Mechanical Engineering. Goals for the course include; the introduction to: The Product Realization Process, professional competencies, professional ethics and the development of a basic engineering project. The project includes engineering analysis, market outlook, basic production techniques, economic assessment, planning, design, manufacturing, testing and product evaluation. The focus of the other course is to further develop required skills in mathematics and engineering science and learning the use of computer programming for the solution of engineering problems. The approach taken in both courses is project/goal oriented, learning topics are "discovered" as part of the project development. In one course, hands-on experimentation is emphasized while in the other analysis and numerical simulation are promoted. The experience of the past few years indicates that retention has improved when students take one of these courses during their first semester at the university.

I. Introduction

Retention of Undergraduate Students in Engineering is a topic that may remain perennial* for many years to come as long as a new culture change does not take place in academia to seek new ways to assisting students to value engineering programs as opposed to "trying to weed out the weak or in otherwise judged; undeserving student population".

The throughput of engineering programs (present situation) in non-judgmental terms can be stated as: "the outcomes" of present practices that has led to a shortage of U. S. engineers to meet the needs of our industry during these critical times as the U.S. industry competes to expand in a global economy. As a result of this shortage U.S. corporations, both large and small have to import engineering support from abroad to stay viable in the market place.

The question at hand is: What can be done to increase attracting and retaining engineering students in their respective programs?. Fortunately there have been a significant number of studies and analysis to sort out the elements that cause students to leave engineering programs. One of them provides a good summary of circumstances for which, both engineering and science and math programs students drop out or change majors. An article entitled "Why They Leave" published in Prism on February 1992 addresses some of these issues.
Some of these studies do address even gender differences and gender based reasons why students lose interest in the engineering/science/mathematics programs.

II. Situation to Resolve

Meeting the needs of students to complete successfully their academic program and at the same time, supporting the U.S. industry and U.S. governmental agencies to meet their needs of competent U.S. engineering graduates in order to retain a highly competitive place in the global economy.

While achieving a significant increase in the number of U.S. graduates in science, mathematics and engineering is a complex problem that requires the participation of many parties, engineering schools have a critical role to play to improve engineering student retention.

Engineering students face unexpected difficulties to complete their program. Without being comprehensive, among them we can list the following: a) Ineffective advising both in the academic curriculum and regarding the profession, b) low quality of teaching; c) unavailability of faculty members; d) length for degree in excess of four years; and e) low grades in science courses (Mathematics, Physics and Chemistry) that are prerequisites to major engineering

* (See also: Karan Watson, "Retention of Undergraduate Students in Engineering)

courses. Other student's difficulties that are not discussed here are: financial, perception of lifestyles, lack of study groups and others that fall outside the sphere of influence of engineering departments or schools.

Most engineering programs lose their largest percentage of students during the freshman and sophomore years. The drop-out rates for junior and senior years are much smaller in comparison. Therefore it seems reasonable to conclude that better retention practices in the first year of college may produce an improvement in retention.

III. Strategy for Retention.

The Mechanical Engineering Department at Alabama A&M University is investing resources and efforts to improve retention rates of engineering freshman through two required freshman courses in mechanical engineering. These courses are ME 101 Introduction to Mechanical Engineering and ME 104 Engineering Analysis and Computing. ME 101 is delivered in one hour lecture and three hours of laboratory. The ME 104 class is delivered as a three hour lecture within a classroom equipped with computers. These courses showcase the type of activities engineers carry out in the modern practice of the engineering profession.
Through these courses the department tries to alleviate some of the difficulties facing students as discussed earlier. By having engineering faculty interacting with students during the first year, the faculty is in a better position to advise and help students with questions regarding the program, the university and the profession. The instructors of these courses can help explain students about the usefulness of science courses in the engineering field. Through examples in class or out of the class, students can ask questions on theoretical concepts difficult to understand in abstract form.
In addition to this effort, a student handbook was developed to assist students with some of the most frequent questions asked, as per the university's advising center, and with a listing of student paperwork filings required to meet university and department requirements for graduation.

One of the goals of ME 101 Introduction to Mechanical Engineering is that students develop an appreciation for those engineering competencies that may enhance their employment opportunities. The authors have adapted/developed materials and examples from several sources for the introductory freshman course in Mechanical Engineering. Other goals for the course include their introduction to: The Product Realization Process, professional competencies, professional ethics and the development of a basic engineering project. The project includes basic/fundamental engineering analysis, market outlook, basic production techniques, economic assessment, planning, design, manufacturing, testing and product evaluation.

The focus of ME 104 Engineering Analysis and Computing, is to further develop required skills in mathematics and engineering science and learning the use of computer programming for the solution of engineering problems.

The approach taken in both courses is project/goal oriented, learning topics are discovered as part of the project development. In ME 101, hands-on experimentation is emphasized while in ME 104 analysis and numerical simulations are promoted. Both courses contain optional advanced topics that may be covered as time allows.

A special effort was made to monitor closely student performance. When performance by a student was unsatisfactory, the instructor called the student for a meeting to discuss what kind of difficulties the student experience. Suggestions were made regarding learning styles and review of good study techniques/habits. Student performance was discussed with his/her faculty advisor so that additional assistance could be given if needed.

For one sections of ME 101, the mid-term average GPA was 3 .0 and at the end of the semester was 3.25. For a second section of the same class the mid-term average GPA was 2.74 and went up to 3.6 by the end of the semester. For the ME 104 class the mid-term average GPA was 3.14 and it went up to 3.67 by the end of the semester. The drop out rate by mid-semester was one out of nineteen for both classes. The authors consider that the student-instructor conferences scheduled based on early lower scores were beneficial in the overall class performance.

For ME 101, the experience of the past few years indicates that retention has improved when students have taken the ME 101 class during their first semester at the university. ME 104 has been offered only once at the time of the writing of this paper. Student's comments about the class have been very positive, student's self-confidence is good and specific results of this particular course on retention will be part of continuing this study in a future paper.

The courses are integrated with the rest of the curriculum and are designed to address the ABET accreditation criteria regarding both content and outcome oriented. The details of each course content is shown in appendix A and appendix B respectively.

IV. Results

The Mechanical engineering program at AAMU officially started in the Fall of 1997. During the second year it was found that close to 50% of the first year freshman class did not remain in the program. At that time the ME 101 class was offered only in the second semester of the freshman year. A decision was made to offer the class both in the fall and spring semesters for the following years. Figure 1 shows the cumulative enrollment to fall 2000.

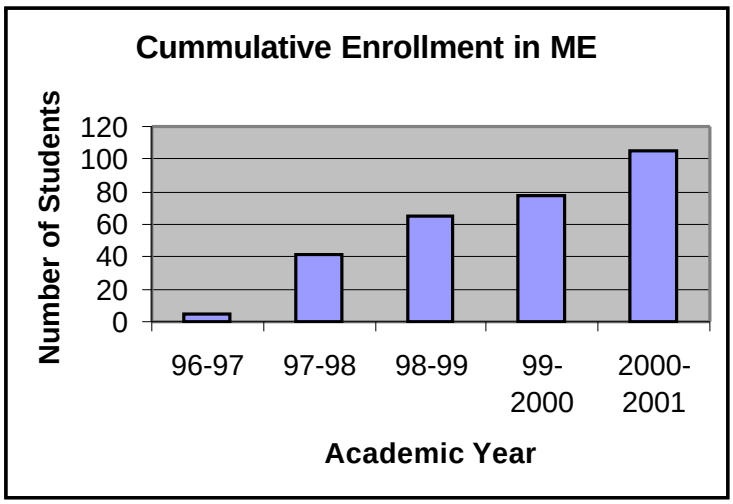

Figure 1. Cumulative Enrollment to Fall 2000

As a result of the ME 101 course offered both in the fall and the spring semesters, the retention rate increased significantly when compared with the results of the first year. The results are shown in Figure 2.

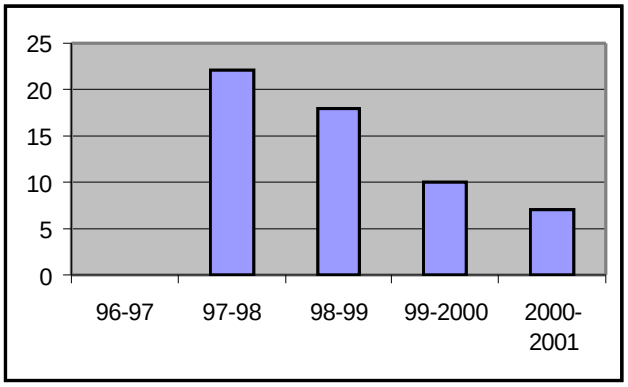

Figure 2. Non-Returning Students (Changing majors, On probation, Suspended and No-show. est.)

During the past three years there has been only one junior level student that changed majors. Other than that case all junior students have been able to complete the engineering program.

V. Conclusions

Adjusting the mechanical engineering curricula to include two freshman level courses has resulted in a significant improved retention of undergraduate students in the program. The

retention rate has improved through out the past three years significantly when ME 101 was offered twice a year. The addition of a second freshman course (ME 104) is expected to continue to improve undergraduate student performance through their academic program.

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Cathy Qian is Assistant Professor of the Department of Mechanical Engineering at Alabama A&M University in Huntsville, AL. Dr. Qian has an extensive background and research experience in systems engineering, numerical simulation in particular high speed flows and heat transfer phenomena. She earned her Ph.D., in Mechanical Engineering, University of Tennessee, 1994, and her MS in Aerospace Engineering from the U.T. 1988 Bachelor of Science in Aerospace and Mechanical Engineering, from Beijing University of Aeronautics and Astronautics in 1985.

Appendix A

ME 101 - INTRODUCTION TO MECHANICAL ENGINEERING
FALL/SPRING SEMESTER 2002

Catalog Data: ME 101 *Introduction to Mechanical Engineering* - 1 hrs. (Lec. 1 hr.) Mechanical engineering as a practice is reviewed briefly. Students are required to develop a basic engineering project to include: Market outlook, basic production techniques, economic assessment, planning and design, manufacturing, testing, and product evaluation. A final technical report is required. The report includes an oral presentation and documentation in writing. Emphasis is placed on team development, consistent use of engineering units, and computer usage. Project selection is under the the instructor's approval**. Prerequisite: MTH 104 or consent of instructor** Co-requisite ME 101 L.

ME 101L *Introduction. to Mechanical Engineering Lab* - 1cr. hr. (Lab.3 hrs.) This laboratory is required to develop the project/s associated with ME 101

TextBook: Instructor class notes

Coordinator: Dr. Ruben Rojas-Oviedo.
Instructor: Dr. Ruben Rojas-Oviedo / Dr. Cathy Qian

Objective: This course is designed to provide the student with information regarding the engineering competencies and attributes demanded in today's engineering environment from engineering graduates. The student should be able to develop a personal pre-professional plan to develop such competencies. The student is expected to take a pro-active role in defining and assessing metrics that demonstrate the outcomes of their pre-professional plan. The student will start his/her design portfolio with a class project and will register it at the ME Department Office.

Prerequisites by topic:

1. Solution of algebraic equations; 2. Fundamentals of physics; 3. Basics of English composition; 4. Basic drawing

Topics:
1. Intro to modern engineering profile. 1period (50 min.) (1p)
2. Preliminary design of a pre-professional plan - identifying learning process SEA-ARK – understanding engineering requirements and goals. Stating Engineering problems (1p)
3. Tools for Problem Solving - The Team-work methodology -Decision Making- Brainstorming- Code of Cooperation- Experiment on Back to Back (no visual contact) unilateral-communication (1.5p)
4. Intro to the Product Realization Process. (IPPD Process) – Structuring of a Story,\

A product, Bicycle Team Design Reviews. A two min. glider –(Lab session)

5. Project definition (A glider project)
   Product/process definition-Requirements: Performance, Safety, Manufacturability.
6. Paths to success. Understanding the Problem, (A good story teller), Early Planning, Understanding the Evaluation Metrics, (Good Reporting), Organization.
7. The business perspective, vision and the big picture. Learn What You Need to Know – Performance Requirements for a Glider. – Discussion of Space Shuttle Re-entry Trajectory- (rate of descend, payload, weight determination by major components- statistical analysis of aircraft 3p)
8. Basics of Glider Design - Aerodynamics – Forces in Equilibrium- Prototyping – Testing – Evaluation – Fine Tuning – (3 p)
9. Weigh Analysis - Market analysis for Materials. (1.lab)
10. Materials and Materials Selection - Examples and Practice – (1.5 lab session)
11. Learning Styles – Kolb – Team effects (.5 p)
12. Market outlook, market research, The Commercial Satellite Market-launchers
13. The Bernoulli's Equation-Wind Tunnel. Demonstration of flow in conv-diverging passage.
14. Calculation of Lift and Drag.(1p, 1Lab) - basic wind tunnel testing-
15. Evaluating alternative materials/ products
16. Teamwork practices - Planning Process; Basic resource analysis / allocation / lists /assignments to project members / resource cost reporting./ (Teams Homework)
17. Time line practice - Resources and task scheduling. Mentor Eval. Practice (1p)-Optional-
18. Conflict Resolution and Professional Ethics. Examples – Role Play (2 lab sessions)
19. Production techniques (.5p)
20. Manufacturing, testing, and product evaluation. (1p + 1lab)
21. A final technical report - hints-

ABET category content as estimated by coordinator:

Engineering science: 1.5 credits…..(includes the lab portion)
Engineering design: 0.5 credits…..(includes the lab portion)

Project:

Students will participate as team members to develop a project as determined by the instructor. The project selection will be defined within the second week of classes and students will submit their report a week before the last class of the semester. Students will include a copy of their report in their "Design Practices Portfolio".

Grading: 2 Test of equal weight for 50% . Lab Report and Homework counts for 15%, Project for 15 % and Final Exam for 20 % of the final grade.
No make-up test will be given except under extreme circumstances and by previous agreement. Homework is due the following meeting after the homework has been assigned or as indicated by instructor. Homework will be accepted late only once. Further late homework will not be accepted.

Prepared by Dr. Ruben Rojas-Oviedo. Revision Date: Jan, 2002.

Appendix B
ME 104 Engineering Analysis and Computing I (3 credits)
Spring Semester 2002

Catalog Data: ME 104 : Introduction to problem solving techniques in engineering science problems using digital computers and Fortran programming. Topics include flow-charting and primary emphasis is on the analysis and solution of science problems in fluid dynamics, materials, structures and energy systems performance. Fundamentals of linear algebra are covered. Prerequisites: MTH 112.

Textbook: Instructor Class notes.

References: Advanced Scientific Fortran
David R. Willé, Ciba-Geigy AG, Basel, Switzerland
Published: Jul 1995; Copyright: 1995; Imprint: John Wiley & Sons Ltd.

Coordinator: Ruben Rojas-Oviedo.
Instructor: Dr. Ruben Rojas-Oviedo, Dr. Cathy Qian

Goals: This course is designed to provide freshman in engineering the ability to develop and understanding of the basic elements of engineering analysis. Combining sciences, engineering and mathematics to develop computer programming skills. Students develop modules necessary to evaluate the performance of mechanical, thermal and fluid systems. Constraint equations are discussed and the fundamentals of linear algebra are employed in their solution. (Optional). The instructor may choose examples applicable to aeronautical systems, mechanical systems or electrical systems.

Topics:

1. Introduction to Engineering Analysis. Discussion of typical problem formulation. (Take off problem) Mathematical modeling and advantages of computer simulation.
2. Introduction to Fortran programming.
3. The atmosphere. The perfect gas law. Systems of units. Pressure, gage pressure, etc. Standard atmosphere equations hydrostatic and atmospheric pressure. Computer Program- The atmosphere.
4. Basic Engineering Fluids nomenclature and equations. Bernoulli's equation definition, speed of sound, viscosity, Shear stress, lift, lift coefficient, drag, drag coefficient, Optional discussion on: pitching moment equation. Altitude, absolute, geometric, geopotential, density altitude etc.
5. Basic Conservation Equations. Conservation of mass, conservation of momentum, conservation of energy. Examples on: Stream Tube, venturi effect. Airfoils and streamtubes. The wind tunnel. Wind tunnel experiments, manometric pressure readings. Data sets, 2-D matrices, Arrays, Introduction to Do-loops, Computer program- calculation of lift for a wing.

6. The momentum equation, friction and the Bernoulli's equation. Fundamentals of Thermodynamics and the energy equation. Isentropic concepts in fluid flow. compressible flow concept, the Mach number. Computer program-Evaluation of pressure ratios for frictionless incompressible and compressible flows
7. Speed of sound equation. Acoustic propagation. Relative velocity concept. Moving sound source, Mach cone. Problems with near sonic conditions in different media. – minimum Flight speed.
8. Engineering structures and materials. Trusses, beams, Airfoils. Common Alloys, Nomenclature, definitions, Figures of merit. Optional: Elastic Deformation, Energy Absorption. Computer program- numerical determination of areas under curves. numerical accuracy.
9. Mechanical, Thermal, Electronic Performance. Figures of merit. Equations of motion . Thrust required, Power required for take-off.
10 System modeling, Optional: Discussion of Equations of constraint. Fundamentals of linear algebra. Computer Program-Solution of systems of equations with two and three unknowns.
11. Optional: Fundamentals of Matrix algebra. Computer program-Determinants, Inverses, Diagonalization.

Computer Usage: 30%
Laboratory Projects:
A selected problem in the Analysis of Mechanical, Thermal, Electrical of Fluid Systems with regard to performance.

Estimated ABET Category content:

Engineering Science:	1units
Mathematical and Physical Sciences:	2units.

Grading: 2 Test of equal weight for 40% . Homework /Programs counts for 30 %, Two Program Analysis Reports for 25 % and 5% class participation of the final grade. No make-up test will be given except under extreme circumstances and by previous agreement. Homework is due the following meeting after the homework has been assigned or as indicated by instructor. Homework will be accepted late only once. Further late homework will not be accepted for full credit.

Prepared by Dr. Ruben Rojas-Oviedo. Revision Date: Jan., 2002