

AC 2007-188: PERSPECTIVE OF A TRANSFER ENGINEERING PROGRAM

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Perspective of a Transfer Engineering Program

Abstract

The transfer engineering program at Albany State University conducted in collaboration with Georgia Institute of Technology has undergone a number of structural changes in the last five years leading to a more comprehensive educational experience for the students that have been reflected in higher enrollment figure and improved matriculation rate. Curriculum enhancement with introduction of five new engineering courses and revamping the materials of others to ensure smooth transition to Georgia Tech, addition of laboratory component to the engineering courses, conducting workshops for high school students and organizing annual model bridge building competition, have not only allowed the current students to experience a deeper appreciation of the subject matter but also provided prospective students a taste of engineering career. The program still faces a serious challenge of attrition due to the problems experienced at the sophomore level courses for which remedial measure is considered in the form of a bridge course in application oriented mathematics.

Introduction

Albany State University (ASU), a premier historically black university, located in southwest Georgia conducts a transfer engineering program with Georgia Institute of Technology (Georgia Tech), the state's only public university offering four year engineering degree. The Regent's Engineering Transfer Program (2+2) started in the mid-80's, with a handful of universities participating, provides students from all over the state to complete the first two years closer to home before transferring to the junior level at Georgia Tech. Currently 14 colleges and universities throughout the state of Georgia participate in this program. Students also can participate in the Dual Degree Program (3+2), where they have to spend an extra year at ASU to obtain an additional degree in a science major upon completion of the engineering degree at Georgia Tech. Over 90% students of ASU belong to the African American community as well as the entire group of engineering students which currently stands at around 50. Though the program was primarily designed for transfer to Georgia Tech, in the past ASU students have matriculated to various other universities to complete their engineering degree program.

Details of the Engineering Program

Beginning with the academic year 1989-90, when 2 students first transferred to Georgia Tech, as of fall 2006 a total of 32 students have matriculated from ASU to Georgia Tech. Among these, 17 students have graduated from 5 different engineering majors and 10 are currently enrolled at Georgia Tech, resulting in an 84.4% success rate for the program. This figure compares very well with the equivalent figures (72% to 92%) for the rest of the colleges and universities in Georgia participating in the same program validating the success of our program. There is reason to believe that this level of achievement has been possible due to the changes implemented in the past five years as will be discussed here.

Though the admission requirements suggested by Georgia Tech in terms of SAT score and high school GPA for the transfer students are modest compared to direct admission, often times our engineering students fail to meet them as ASU allows an open admission policy. In order to

transfer to Georgia Tech, a student has to complete at the host institutions the entire institutional core as well as the courses in humanities, science and social science as required by the Board of Regents of Georgia. Calculus based Physics I & II, Calculus I, II & III, Ordinary Differential Equations, Linear Algebra and General Chemistry I along with another lab based science course constitute the science and mathematics course requirements. Some major programs, (Chemical & Bio-medical engineering) require General Chemistry II, Organic and Physical Chemistry also. Computer Science requirement at Georgia Tech has changed over the years and is some what flexible. Transfer students are allowed admission to Georgia Tech if they can secure at least a minimum overall GPA of 2.7 as well as GPA of 2.7 in science and mathematics courses too. There is no specific requirement of completing a set of engineering courses in order to transfer and has been left to the resources available in the participating institutions. However, from the available statistics it has been observed that students have a better chance of succeeding at Georgia Tech if they complete at least some of the freshman and sophomore level engineering courses required by the respective engineering degree programs.

New and Updated Engineering Courses

Though the original intent of the transfer program was to ensure that the students will just have to complete the common science and humanities core required by all the engineering departments, in reality most departments require specialized courses in the first two years of their programs which are prerequisites for the upper level courses. Hence, ASU required all students to complete some of the engineering courses before transferring. Also, in order to keep abreast with the changing technology, many departments at Georgia Tech have periodically added new courses for their students. As a result, it was felt necessary to offer the same courses at ASU in order to ensure seamless transfer. Since the academic year 2000-01 a number of new courses have been added to our engineering curriculum and some courses have been updated to bring them in line with the courses required by various departments at Georgia Tech. Following is a brief description of the new and updated courses currently being taught at ASU. The first time each of these courses was taught is shown in parenthesis.

a) ENGR 1200 – Engineering Computing (Spring 2001)

This is the first course in computing for the engineering students. Most students take it in their first semester of freshman year. This course is designed to provide engineering majors a foundation of computing with an emphasis on design and implementation of algorithms that complement and support engineering problem solving. The course helps students in pursuing the engineering curriculum, which requires them to use computers for communication, literature search, word processing, presentation graphics, mathematical analysis, data analysis and numerical problem solving in specialized engineering applications. Students are exposed to some applications program (Word, PowerPoint), then introduced to computing initially by working problems in EXCEL. Last two thirds of the course is devoted to teaching and working with MATLAB programming language. The course concludes with a brief introduction to JAVA language. This course is currently taught in every fall semester.

This course is followed by another course CSCI 1301 – Computer Science I, which is taught system wide in Georgia. CSCI 1301 is taught through the JAVA language entirely. Though

these two courses are sufficient for most of the engineering majors, Electrical, Computer and Industrial Engineering majors have to take a third course in Object Oriented Programming at Georgia Tech.

b) ENGR 2025 – Introduction to Signal Processing (Spring 2001)

This course is designed to introduce students the concepts of analog and digital signal processing that includes principles and procedures of discrete-time and continuous time signals. Topics on filtering, frequency response, Fourier transform, Z transform are included in the course. The laboratory emphasizes computer-based signal processing utilizing MATLAB software.

This course is equivalent to the course offered by Electrical and Computer Engineering department of Georgia Tech and is a required sophomore level course for Electrical and Computer engineering majors.

c) CSCI 2030 – Introduction to Computer Engineering (Spring 2001)

This course covers computer systems and digital design principles which include architectural concepts, number systems, Boolean algebra, logic circuits, combinational data-path elements, sequential logic, and storage elements. Finally, it covers DRAM control and I/O bus.

This course is taught in every spring semester by ASU's Computer Science department and is equivalent to Georgia Tech's course of the same name that is also a required course for Electrical and Computer engineering majors at the sophomore level.

d) ENGR 2001 – Introduction to Engineering Materials (Spring 2004)

Primary objective of this course is to introduce students to the study of engineering materials. Building on an understanding of atomic structure and chemical bonding taught in General Chemistry, students are introduced to the chemical and size-factors which determines the way in which atoms pack together in solid materials. Crystal structures, imperfections and microstructural development (phase diagram) and its modification due to heat treatment are covered. Based on this knowledge, students are introduced to the mechanical, electrical, chemical and thermal properties of many of the structural materials. Material selection and processing is also covered as part of the engineering design. In a companion laboratory class, students work as teams by going through different stages of polishing, then etching to observe the microstructure of 1040 steel, brass and aluminum in a metallurgical microscope followed by Brinell hardness test. Subsequently, they conduct heat treatment of the specimens and repeat the previous steps to reveal the change in the microstructure and hardness number.

This is a required sophomore level course in most engineering majors at Georgia Tech. For the remaining departments, students can get credit for this course as an engineering elective. As such, this course is taught every spring at ASU.

e) ENGR 2201 – Engineering Statics (Fall 2006)

In this course, the principles of statics (vector based) in two and three dimensions is covered. Concept of force, moment, equilibrium principle, truss, center of gravity and friction is taught by solving realistic problems.

This course evolved from an older 4 credit hour course on “Statics and Mechanics of Materials” as a response to Georgia Tech’s separating their “Introduction to Mechanics” course into “Statics” and “Deformable Bodies” courses in order to provide more time for in depth discussion in some topics. As per the new requirement at Georgia Tech all engineering majors must take both these courses. Hence, at ASU we have made ENGR 2201 mandatory for our transfer students and it will be taught at every fall semester. In future a new course covering the topics of “Deformable Bodies” would be developed.

In addition to the new engineering courses mentioned above, two more courses were significantly updated with new content in the laboratory software and projects in recent past.

f) ENGR 1203 – Engineering Graphics (Fall 2001)

This is a traditional introductory level course in engineering graphics and design including sketching, drawing, projection theory, tolerances and computer-aided graphics. This course was changed from a two hour to three hour course in order to provide more time in developing three dimensional solid modeling. Students use SolidWorks software to draw 2D sketches and then convert them to 3D model by either extrude, revolve, sweep or loft commands. At least one assembly project, where multiple solids have to be mated keeping in view of mutual interference and relative movements is also covered.

This course is required for only Mechanical, Aerospace and Civil engineering majors at Georgia Tech. As there is always sufficient number of students enrolled in those majors, this course is taught at least once every year.

g) ENGR 1103 – Principles of Engineering Analysis and Design (Fall 2002)

This is comparable to “Introduction to Engineering” course as is customarily taught in most engineering programs. The only difference is that ASU course is taught at sophomore level instead of the freshman level with pre-calculus as prerequisite. Primarily, this course introduces students to the engineering career opportunity, course requirements, survival skills, team work, technical communications, design approach, and ethical practices. The course is also used to reinforce concepts learnt in algebra and trigonometry and introduce principles of the engineering sciences such as mechanics, thermodynamics and electric circuits.

In 2001 an Engineering Laboratory was established with the funding secured from the Department of Education’s Minority Science and Engineering Improvement Program (MSEIP). It was decided to use ENGR 1103 to introduce students to the laboratory equipment so that they can gain an understanding of the practical problem solving approach

adopted by practicing engineers. As such this three credit course was changed from lecture only to a two hour lecture and a three hour laboratory classes per week.

Apart from the above new or modified courses, ASU continues to offer one existing engineering course, “ENGR 2413 – Electric Circuit Analysis” in the spring semester which requires Physics II as a prerequisite. This course and “ENGR 2025 – Signal Processing” are required only for Electrical and Computer Engineering students and as such are offered only when there are sufficient numbers of students in those major areas.

Engineering Laboratory

As mentioned previously, an Engineering Laboratory with a few computer-controlled manufacturing and testing machines was established in the fall of 2001 from the funding obtained from the Department of Education. These machines are:

- FLOTEK 1440 Open Circuit Subsonic Wind Tunnel with 3' x 1' test section
- EMCO PC Turn 55, 2 axis CNC machine
- Stratasys Dimension 3D Printer
- Tinius Olsen H50K-S 50 kN Bench Top Universal Testing Machine
- Axiovert inverted microscope, Hitachi color camera and image analysis workstation

A set of 8 programmable Lego-Mindstrom robots were also purchased from a separate grant from Georgia Space Grant Consortium, a funding agency of NASA.

The detail description of the laboratory equipment is available in the ASU’s engineering website¹. A total of twelve experiments were developed with these set of equipment specifically for our transfer engineering students. These experiments were published as a supplementary textbook² to support the lab component of the course ENGR 1103. Students work in a batch of 2 to 3 to complete about 8 of the 12 experiments in a semester.

The goal of the experimentation is not as much to provide mastery of any specific engineering discipline, but to facilitate development of critical thinking ability on the part of the students so that they can independently analyze the experimentally observed data to arrive at an understanding of the underlying physical phenomenon.

Brief Description of some of the Experiments:

a) Assembling and Programming Robots

These very popular and relatively inexpensive robots are created by snapping together conventional Lego blocks around a programmable RCX brick, which has its own microchip and operating systems. In its most basic version, the RCX uses sensors to take input from the environment, processes the data and signals up to three motors or lamps on or off in any one of five power levels. Icon based programming is done in RoboLAB language, a simplified version of LabVIEW.

Instruction set for a typical student project for “Car” robot is:

- (i) The car will go forward when the “Run” button is pressed.
- (ii) When the car hits an obstruction, which causes the bar in front to be pushed, it will go in reverse, the light in the back of the robot will be turned on and the wheel on the top will start turning.
- (iii) While going in reverse, when the car crosses a dark line, it will stop, light will be turned off, wheel on top will stop turning and the first line of “Row Row Row your boat” will be played.
- (iv) If the bar in front of the car is pushed again, step (i) through (iii) will be repeated.

Students translate these instructions into functional steps for the specific robot they are working with and then develop the RoboLAB program which is downloaded via the infrared transmitter. Several iterations is frequently needed as is help from the instructor to exactly produce the required operations of the robots as required by the project statement.

b) Developing CAD/CAM program and Machining a Chess Piece in CNC machine

PC Turn 55 is a 2-axis PC-controlled CNC benchtop lathe with programmable tool turret that can accommodate up to 3 external and 3 internal turning, boring, threading or parting-off tools. This lathe is capable of performing all of the classic lathe operations common to full-size machines. This machine is controlled by WinCAM software that is particularly suited for training students to get familiar with all aspects of CAD/CAM assisted NC programming within a very short period. WinCAM has three programming modes:

- CAD (computer aided design),
- CAM (computer aided manufacturing)
- NC (numerical controlled machining)

WinCAM helps create an on-screen graphic work piece in the CAD mode, then an NC program is generated in the CAM mode by means of various machining cycle. The NC program can be processed either directly to machine the part from stock or can be transmitted to a full size CNC industrial machine. The graphic simulation included in the WinCAM shows an exact copy of the machining process and is responsible for a better understanding of the programming sequence and for more safety during program creation.

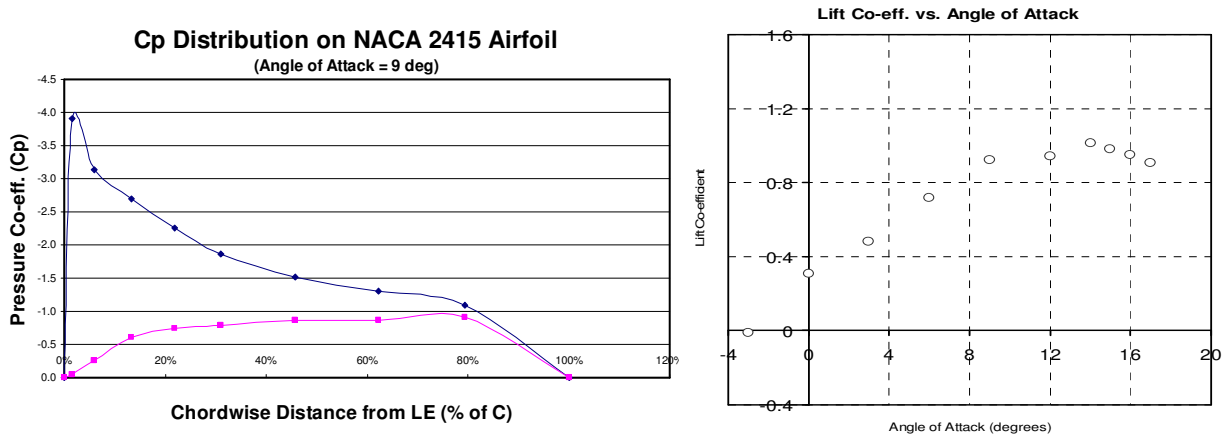
Students are asked to machine a chess piece from the known coordinates of the profile from a one inch diameter ABS plastics stock. They first design the profile in the CAD mode, program the cutting tool path and associate speed and feed in the CAM mode and finally machine the part in the NC mode. WinCAM being an icon driven software, all the programming is done by clicking on appropriate icons instead of writing the program on a text based computer language.

c) Determination of Lift Characteristics including onset of stall on a NACA airfoil

ASU’s wind tunnel is a computer controlled subsonic tunnel with 12” x 12” x 36” test section that is fitted with a 20-tube manometer for enhanced visual reference and a two-component balance beam for measurement of drag and side force. Computer data acquisition system consists of 16 pressure transducers, 16 channels analog to digital and two channels digital to analog capability. LabVIEW software allows real time display of up

to 16 readings of pressure and velocity over the test object while controlling the angle of attack and fan rpm.

In this experiment, student working in a team of 2 or 3 manually record the height of water columns from the manometer tubes connected to the 16 pressure tapings on a NACA airfoil's upper and lower surfaces. Then they insert this information in a preformatted EXCEL spreadsheet to compute pressure distribution and the lift generated for one angle of attack per team. Combined results from the entire class, when plotted, demonstrate the variation of lift coefficient as a function of angle of attack for the given airfoil. The plot also reveals the stall angle and the maximum overall lift attained. The short threads mounted on top of the airfoil (tufts), start vibrating as the stall approaches as does the sudden drop in height of the water column in the manometer tubes. Students get a visual reinforcement of the practical nature of fluid flow and a lesson in teamwork as their collective work is judged how well the lift characteristic of the airfoil has been evaluated.



d) Developing solid models by SolidWorks 3D software and making 3D part in the 3D Printer

In this experiment of developing and making the candlestick, the body is an axisymmetric object obtained by revolving the given profile against the central axis and the handle is obtained by sweeping the elliptical profile along the given path. Students create the 2D



sketch in SolidWorks by line and arc menu commands and dimensioning them accordingly.

3D solid is created by using revolve and sweep features. Students get a better feel in three dimensional spatial relationships from developing the solid model of this very recognizable object.

ASU's 3D Printer is a popular Rapid Prototyping machine based on Fused Deposition Modeling (FDM). Creating prototypes is an important part of the product development cycle. Prototypes enable form, fit, and function testing as well as an useful ergonomic evaluation and marketing tool. In the FDM process, plastic is heated and extruded through a small orifice to lay down material one layer at a time. The CAD file created in SolidWorks is made available to the software called Catalyst in the STL format. STL file approximates the geometry in the CAD file by constructing a mesh of triangular elements (as few as possible) to represent the part accurately. The solid model can be scaled and rotated about all the 3 axes before producing the solid part by Catalyst. Once the processed STL file is submitted by Catalyst to the 3D printer, the solid model is made automatically. Afterwards, cleaning from the support material and finishing has to be done manually.

This project exposes students to the process of designing, developing solid model in the computer and creating prototype that can be examined in closer detail to test fitting and functionality before initiation of large scale production.

e) Observing microstructure of metals and the effect of heat treatment

Students working in teams prepare metal samples by polishing the given specimen with various grades of sand papers, diamond paste, alumina suspension and etching with the recommended solution. The resulting microstructure is observed in Axiovert metallurgical microscope, digitally captured in the color camera and compared before and after heat treatment. Students also conduct a Brinell hardness test in the Tinius Olsen Universal Testing Machine (UTM) before and after heat treatment to observe change in the hardness number. UTM is also used to demonstrate the traditional tensile test on various structural materials. These experiments are conducted in support of "ENGR 2001- Introduction to Engineering Materials", a sophomore level engineering course.

Saturday Workshops

Since 2001, every fall semester, Albany State University is sponsoring a series of Saturday workshops to train selected students from the area high schools in some of the laboratory experiments on the computer controlled testing and manufacturing equipment described above. In the first year workshops were conducted for just half a day with assembling and programming the robots only. Subsequently, more experiments were added as more equipment were installed. Currently, besides robots, students get an opportunity to work on CNC machine, SolidWorks 3D modeling, making the part in 3D Printer and demonstration of wind tunnel experiment in flight / stall of the wing in a daylong workshop. Because of the limitation of time, students need more help and encouragement in completion of their task. In general about 15 students participate in each workshop from each of the high schools accompanied by their teacher. The workshops are sponsored by Georgia Space Grant Consortium which is entirely funded by NASA and is intended to fulfill the space agency's future workforce development plan.

Workshops are also conducted during the semester, especially summer school break for a shorter span for about 2 hours. In the recent past, various workshops are held under the projects called Academy of Excellence, Jump Start and HBCU –Undergraduate Program with participants spanning from middle schools students to incoming freshmen that were funded by Department of Labor, Education and other federal agencies.

Bridge Building Contest

The most celebrated outreach activity conducted by Albany State University’s engineering program is the annual Southwest Georgia Regional Model Bridge Building Competition. Started in 2003, it has become a focal point among the high school science teachers and students in this region. The competition is held on the last Saturday of the month of February to celebrate the National Engineer’s Week. The primary intent of the competition is to create awareness among high school students and their parents about the engineering profession. This event also is sponsored by Georgia Space Grant Consortium. The details of the bridge building competition can be found in the website³.

The competition provides an opportunity for high school students in Southwest Georgia, working as a team of 2 or 3, to solve realistic engineering problems by designing and building a structurally efficient balsa wood bridge according to very demanding specifications. The structural efficiency is measured by the ratio of the breaking load to the weight of the bridge. A panel of judges from industry and research organizations conducts the testing and declares the winners. The competition is held in two categories, short (22”) and long (33”) span, with the weight of the bridge limited to 28.3 gm (1 ounce) and 50 gm respectively. The top three winning teams in both categories are awarded cash prizes. Also, the winners in both categories are given trophies. The high school with the best overall team performance is awarded the commemorative plaque that records winners from the past years. All participants (students and teachers) get free commemorating T-shirts.

With a modest beginning of 16 teams consisting of 42 students in 2003, the competition grew to 46 teams consisting of around 85 students representing 5 high schools that participated in 2006. The quality of the entries also far exceeded the figures of earlier years. In the short span category the structural efficiency improved from 366 in 2003 to 542 in 2006. The maximum breaking load also increased from a previous record of 10.3 to 13.3 kg. The long span category, introduced last year saw the highest structural efficiency attained as 183. Most encouraging news of last year’s competition was that five of the six winning teams in the two categories including the two first place teams belonged to the African-American community even though they were heavily outnumbered.

Current Status and Future Challenges

Table 1 shows the matriculation rate of ASU students to Georgia Tech since the beginning of the Regents Engineering Transfer Program. This number has fluctuated considerably over the years, but shows a gradual upward trend. In order to understand this trend better, matriculation data has been grouped for every five years and displayed in Table 2. As is clearly seen, the total

matriculation in the past five years is the same as the combined total in the previous ten years, which is a testament of the success of restructuring of our engineering program.

1989-90	2
1990-91	0
1991-92	0
1992-93	3
1993-94	0
1994-95	3
1995-96	2
1996-97	3
1997-98	0
1998-99	1
1999-00	1
2000-01	1
2001 - 02	4
2002 - 03	2
2003 - 04	2
2004 -05	1
2005 - 06	5

Table 1: Annual Matriculation Rate to Georgia Tech

1991 - 1995	8
1996 - 2001	6
2001 - 2006	14

Table 2: Total Number of Students Matriculating to Georgia Tech in every 5 years

Table 3 shows the annual number of incoming freshmen and the total number of students in the engineering program in the last six years. It is very encouraging to see this year’s enrollment number at an all time high. But as the total enrollment has remained fairly stable (around 50), one has to conclude that an increasing number of students are dropping out of the program.

Academic Year	Incoming Freshmen	Total Number of Engineering Students
2001 - 02	12	57
2002 - 03	19	54
2003 - 04	21	54
2004 - 05	19	43
2005 - 06	15	43
2006 - 07	31	53

Table 3: Overall View of the Engineering Program

Much has been reported about engineering attrition^{4,5}. Many of the underlying reasons (disinterest in engineering, lack of fundamental preparation, lack of confidence to succeed etc.) of the high rate of attrition apply for ASU students also. However, the prime reason appears to be the lack of adequate understanding of basic mathematical concepts for a significant percentage of freshmen engineering students as ASU follows an open door admission policy. The new revamped “ENGR 1103 – Principles of Engineering Analysis and Design” course is specifically organized to address this problem. Taught in the sophomore level the course relates word problems into mathematical models that describe the physical situation in mechanics, electrical circuits or economics. Also, students get a taste of hands-on experimentation in various testing and manufacturing equipment and software that encourages them to continue with the engineering program. One on one help in problem solving in all science and engineering courses are provided by student tutors who have already successfully completed those courses. Additionally for all 2000 level engineering courses, an instructor supervised problem solving class is held every week to facilitate students learning the technique of translating word problems into math models and then working out numerical solution to find the result. However, students who require most help may not always avail these opportunities. They are the most prone to feel frustrated in their lack of progress causing them to change major.

Conclusion

The introduction of new courses and laboratory experiments in the engineering curriculum has positively impacted our program as is evidenced by increased matriculation rate. The result of the outreach activity in the form of Bridge Building Competition and Engineering Workshops also has created a greater awareness among the high school seniors which is reflected in very significant improvement in enrollment numbers.

However, retention continues to be a serious issue that is being addressed at all levels. It has been seen at ASU as in other institutions that early intervention and remediation at the freshman and sophomore levels do make a difference in students understanding the concepts better as well as provide confidence to face the challenging tasks ahead in their course work. As such, apart from continuation of academic support in the form of tutoring and additional problem solving classes, a bridge course in application oriented mathematics during the summer preceding the freshman year is being considered, if external funding can be obtained. This course will be used primarily to introduce practical problem solving technique based on mathematical concepts, which constitutes many of the questions in any engineering tests.

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