Middle School Students Participate in Three-Week GEAR-UP Summer Engineering Program at Texas A&M University-Commerce

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Abstract

During June 2003, the Industrial Engineering Department at Texas A&M University-Commerce (TAMUC) hosted 28 middle school students for a three-week GEAR-UP engineering experience. The students were entering grades 7, 8, and 9 for the 2003-2004 academic year, in their respective schools. Students attending the GEAR-UP program were from area middle schools including Sulphur Springs, Greenville, and Commerce, Texas, an area of roughly 250 square miles. Transportation, snacks, and the mid-day lunch were provided to the students who attended class for three consecutive weeks (Monday through Thursday) between 9:00 AM and 12:00 noon. Students participated in an engineering project to design, build, test, market, and compete in a paper airplane competition. The program resulted in 36 classroom contact hours between the faculty and the students in the program.

Three full-time engineering, technology, and educational administration faculty members from TAMUC were involved in daily events that included project management, cost engineering, design engineering, test engineering, and marketing. A competition was held to determine the winning team across two categories – 1) distance and 2) flight endurance. Teams were required to develop their own designs on AutoCAD using construction materials provided only by the instructors, with corresponding costs for each item used in creating the paper airplanes. The paper airplane construction materials were priced individually and were charged to the teams as they were consumed. Students were integrated into functional positions on each team, independent of their individual gender and age level. Of the 17 students who completed the full program and attended the awards ceremony, ten of the students (or approximately 60%) were female. This paper will detail the processes used to create the GEAR-UP experience for the middle school students, including team development, design criteria, processes used, and results of the competition.

Background

GEAR-UP is an acronym for "Gaining Early Awareness and Readiness for Undergraduate Program. It is one of many exciting programs to emerge from the Higher Education Amendments of 1998, which was endorsed by former President Bill Clinton on October 7, 1998."[1] During the first three weeks of June 2003, the Industrial Engineering and Technology Department at Texas A&M University-Commerce hosted students from area middle schools who participated in the first-ever engineering GEAR-UP program in East Texas. The objective of the engineering program was to provide these students with an appreciation of

engineering design and development principles as they competed for prizes and awards for the best-performing designs during the competition. The faculty determined that several engineering principles could be demonstrated to the students by having them serve as members of cross-functional design teams, operating under a matrix-style organizational structure[2] who would work together to develop competing paper airplane designs that would then be flown in competition ten days into the twelve day program. Five teams were created by a random selection process. This was done to limit pre-existing peer-to-peer pairings that would likely influence team performance (positively or negatively) during the three week program. Five functional job titles were created for each team, with one student originally responsible for each function during the early phase of the program. These five functional titles were: 1) Program Manager, 2) Design Engineer, 3) Test Engineer, 4) Marketing Manager, and 5) Finance and Accounting Manager (responsible for Cost Engineering). As a result of some early attrition in the program, due primarily to student summer school commitments and other family obligations, 21 students remained committed to their teams and were able to complete the three week program. Since the five functional jobs on each team remained a cornerstone of the GEAR-UP engineering project, several students had to assume dual roles to account for the attrition on their individual teams. Francis T. Hartman[3] cites six factors as key elements to insure team success: 1) Clear sense of mission, 2) Trust, 3) Job ownership, 4) Alignment, 5) Cohesiveness, and 6) Enthusiasm. All six of these factors were emphasized during the GEAR-UP program to facilitate team performance.

Team Organization and Development

Five teams were originally created with five members on each of four teams, and one team having six members. Teams were instructed to determine a name for their team to be used in marketing and operational settings during the competition. With some guidance from the faculty, the students selected five team names as follows: Orion, Panthers, Avengers, Blackhawks, and Odyssey. During the first week, several students drop from the GEAR-UP program due to outside commitments, leaving their teams short of functional team members. When this occurred, the students in each team reallocate the functional job descriptions among the remaining team members - not unlike the real world when people on the design team are reassigned to other projects, promoted, or removed from the individual project in question. Students quickly learned about responsibility to the team when one or more of their team members were unable (or unwilling) to fulfill their individual responsibilities. Once the team organizational structure began to stabilize, the primary task once again turned to the design, test, and production of the paper airplanes to be used in the competition.

Course Design Criteria and Rules of Conduct

The GEAR-UP program is defined by two complementary efforts: 1) Competitive Grants to States and 2) Competitive Grants to Partnerships (colleges, businesses, school districts, etc.). The primary mission of the program is to provide educational development, training, and leadership for middle school youth by serving as a vehicle to effectively prepare youth with the necessary knowledge and skills for successful academic achievement in high school, in advanced placement courses, and in future college studies. At this time, the TAMUC GEAR-UP Program provides services to 7th, 8th, and 9th grade students of the Commerce, Sulphur Springs, and

Greenville Independent School Districts. Program participants also receive assistance in the form of academic tutoring, educational student/parent workshops, test preparation, Scholarship Information, and Cultural Enrichment Field Trips.[1]

In hosting this program, the Industrial Engineering department at Texas A&M University-Commerce had four major objectives: 1) to introduce middle school students to the role and duties of engineers in today's workplace, 2) to prepare students for college-type courses through an introduction to the physical environment of a college campus and to the class schedule that mimics a typical summer course, 3) to develop an interest in engineering, and 4) to provide a "real-world" individual and team experience for each student who completed the course. It was emphasized from the very beginning that the inability to maintain appropriate classroom behaviors could reverse an otherwise positive experience for all students and result in a negative experience for each participant; therefore, three measures were taken to reduce the advent of classroom disruptions. Three classroom behavior rules were established by the faculty, including: 1) *Ask Three – Then Me*, in an attempt to have students collaborate with their team members to help resolve group issues before asking the instructors for assistance, 2) *Raise Your Hand Before Speaking*, to control activity within the classroom and to manage the flow of conversations between student teams and the instructors, and 3) *Only the Project Manager is Permitted to Ask Questions on Behalf of the Team*, in an effort to have student teams coordinate and define their questions before asking for outside help. These rules were developed and discussed during the first class meeting, along with the introduction of faculty and student assistants who would be involved with the GEAR-UP Program throughout the course. Students were asked to add rules to the list as needed. They created three additional rules relating to team cooperation and performance, coming to class prepared, and behaving in a positive manner. One of the faculty members, a former junior high math teacher, was able to identify, clarify and review issues which might arise with students in this age group, enabling the faculty team to effectively address key issues to insure minimal class disruptions.

Planning and Preparation

Approximately four weeks and again two weeks before the beginning of the GEAR-UP program, the three faculty participants met to define course objectives, to identify materials needed for the course, and to discuss the course structure, goals, discipline procedures, and final course objectives. Daily lesson plans were created to guide the faculty through each day's activities. The lesson plans and activities were reviewed with students at the beginning of each class to keep students focused and on track. During these meetings, it was determined that a simplified federal government procurement process[4] would be modeled wherein a product would be defined, developed, built, tested, and "sold" to the government (in this case, the faculty team itself), following the results of a "fly-off" competition on day ten of the program. The faculty participants determined that a paper airplane competition would reflect these requirements. Two competitions would be held, one for flight endurance (or duration) and the other for flight distance. Affordability would be the third criteria. Ten flights for endurance and ten additional flights for distance were flown by each team during the competition. The average performance values along with affordability were then used to determine the winner in the flight competition itself. The winning team was the team which developed one (or more) paper aircraft that performed best in each event according to endurance and distance, with appropriate

documentation, and with the most competitive costs to the government. Additional requirements were placed on the aircraft design which included: 1) the development of team logos to be placed on the aircraft, using Microsoft PowerPoint and other paint-type programs – a component of the marketing effort, 2) the actual design of the aircraft using AutoCAD – a function of the design engineering team leader on each team, 3) testing the individual prototype designs – a function of the test engineering team members, 4) tracking costs of development and production using Microsoft Excel – a function of the cost engineering team members, and 5) setting the project plan using Microsoft Project – a responsibility of the project manager. Once the aircraft had been flown in competition on Tuesday of week three, the teams returned to the classroom and to the computer laboratories in order to compile a final report and presentation to be delivered during the final awards ceremony on the final day of the program, Thursday of the third week. Since the GEAR-UP program also emphasized parental involvement, assuring a better success rate for students, the awards ceremony was held on campus. An early evening time was set in order to encourage parents and other family members to witness the student's individual and collective efforts in a public forum. The faculty created a weighted evaluation criterion to identify the first place, second place, third place, and honorable mention teams, each receiving medals and/or ribbons for their efforts. All of the final team products were available for review by all parents, faculty, students, and guests during the awards ceremony. Each student team presented their final report using PowerPoint presentations before the assembled group of approximately 50 people.

Design and Production Criterion

Since the GEAR-UP Program was a three week course, it was relatively easy to divide the course into three distinct phases. The first phase involved team development and introduction of engineering tools to be used during the course, including computers, software, and mechanical drawing or drafting equipment. Students were required to develop their own aircraft designs and to place those designs onto AutoCAD before they were printed onto "approved" paper for test flights and for competition. An overview of a design engineer's responsibilities was provided, to include preliminary design processes, critical design processes, production, testing, and flight tests. An overview of classroom responsibilities, relevant university regulations, and common university courtesy issues were also covered and agreed upon by students as part of their commitment to and continued involvement in the GEAR-UP Program. Expectations were mutually developed between facilitators and students to include allowable actions and responses. Students were randomly assigned to their teams during the first day of class and the individual responsible for all five functional titles within each team was defined by the team itself. Of the original 28 students who originally signed up for the GEAR-UP Program, 14 were female students and 14 were male students. After the enrollment stabilized at 21 students, by the end of the first week, 13 female students and 8 male students remained in the program until completion. The attrition rate for female students was approximately 7% while the attrition rate for male students was almost 43%. No attempt was made to determine the reasons for the large discrepancy in attrition rates between male and female students, since this was the first time the engineering GEAR-UP program had been hosted at Texas A&M University-Commerce. Some anecdotal information suggested that summer sports programs and summer school commitments may have played a role in determining the higher attrition rates for male versus female participants. This attrition created

some difficulties for certain teams since some teams lost two or more team members while other teams lost one or no team member. The faculty worked with each team to reallocate functional job descriptions to the remaining team members, by no functional jobs were eliminated throughout the program. One team had to be dissolved due to the extremely high attrition (3 of 5) but the remaining two team members were reassigned to serve as representatives of *the government* by developing rules and regulations for the flight competition and for assisting in the data collection during the fly-off competition. Phase Two of the three-week program was focused on refining aircraft designs, mastering software programs, creating first-draft documents to be used as templates for the final report, and testing the prototype designs before selecting the competition-ready airplanes that would be used early in week three. Phase Three centered on final preparations for the flight competition on Tuesday of week three. Following the flight competition, results and performance data collected from each of the four teams were analyzed and integrated into final team reports for use at the awards program and to determine the *winning* designs in the simulated competition.

In Phase One, students were provided with a glue stick, a small bottle of white glue, a ruler, a compass, and a protractor. All other materials used in the production of aircraft (after day three of the event) had to be "purchased" from the *approved government supplier (faculty members only)* and used in all prototype and/or development paper airplanes. A sample listing of these "raw materials" included: white bond paper = $5,000.00 per sheet; colored bond paper = $7,000.00 per sheet; white card stock paper = $8,000.00 per sheet; colored card stock paper = $10,000.00 per sheet; small paper clips = $500.00 each; large paper clips = $750.00 each; toothpicks = $250.00 each; replacement white glue bottle = $1,000.00 per bottle; photocopying designs onto *approved paper stock* = $500.00 per page. Materials were priced to encourage wise financial choices in purchasing and using required materials as well as minimizing scrap and waste throughout the prototype and production development process, and to model the acquisition process. Project Managers and/or Cost Engineers were required to track all expenses incurred by their teams throughout the development, testing, and operational phases of the program. No cost constraints were placed on student teams, other than the inherent "competition factor" which would decrease the probability of success if a team priced their products too high for the government to afford. These costs were factored into the eliminating process as the winning team was being determined. It is interesting to note that at least one team priced themselves out of the competition, even though their aircraft design performed better in the distance and duration competition than did other team's designs.

Students had two primary responsibilities throughout the program; 1) to work responsibly with their respective team members and 2) to work responsibly with those members of other team members who held the same functional title as they held, simulating a matrix organization[2]. Each day, students would meet in the classroom with their cross-functional teams for the first hour and a half, discussing and resolving design, testing, and program issues with their individual designs. After the morning break, the students would go into their respective computer laboratories where they would work with their functional counterparts learning the respective software programs as described earlier. The computer classrooms were used to teach the students fundamental components of each respective software program. Faculty members would provide a short tutorial during the initial portion of each period, followed by hands-on practice by the students working with their functional counterparts from other teams. For

example, all marketing personnel were tasked with creating the team's presentations on PowerPoint and for providing inputs to the Project Manager for the team's final report. They were also responsible for developing the team's distinctive logo to be used in the marketing material and for use on the aircraft during the official test flights. Each functional team worked together to master their respective software programs in order to complete the program requirements. Instructors provided some initial instruction on each of the software packages, but the functional teams were also expected to share their expertise with other functional team members to improve the overall products for all four teams. This matrix organization[2] was developed to mimic representative organizations involved in government procurements today. The matrix organization allowed students to communicate within the teams and to facilitate communications flow among functional teams, similar to real-world engineering teams.

During the first week, or Phase One of the GEAR-UP Program, students were challenged to develop, design, and build a paper airplane which could be entered into the upcoming flight competition (Phase Three) where they would be judged on distance, flight endurance, and affordability. Some student teams chose to create one aircraft to compete in both the distance and endurance competitions while other teams created two (or more) designs for use during the fly-off competition. During Phase Two, students were encouraged to try several designs early in the development process and to confer with test engineers as to which model(s) performed best during the test phase in both flight distance and flight duration. Once a candidate design (or designs) was (were) selected, the design engineers were responsible for creating AutoCAD drawings with appropriate assembly instructions, so team members could recreate the prototype paper airplanes for the final flight competition. Phase Three was the final week of the program where final preparations were made for the actual paper airplanes to be used in the competition.

Flight Competition and Contract Award

On Tuesday of the third week of the program, the flight test competition was held. The original plan was to hold the competition outdoors, launching the airplanes from the second floor walkway at the Student Union building onto a closed parking lot below. This plan would have provided students with impressive distance and flight durations, but the weather did not cooperate on the designated day of competition, so the entire operations was moved into the gymnasium. Once the flight launch area was defined and the competition rules explained, each team flew their paper airplanes in the distance competition, based on a random selection process. Ten flights were flown for each team before the next team began their flights. Once all 40 flights had been completed for flight distance, the flight duration competition began. Again, each team flew their designated paper airplane in the flight endurance competition and the results of each flight profile were recorded for further analysis.

The final report was prepared by each of the four teams on Wednesday of the third week. The report combined several areas of the teams' experiences, including a report on the design of each aircraft, testing procedures and results of flight tests, detailed coverage of the processes and constraints witnessed in the manufacturability of the paper airplanes, cost accounting results showing how much the teams would charge the government for their individual designs, and finally the results of the Project Manager's planning activities throughout the three week event. As mentioned earlier, each team was responsible for integrating their design, planning,

marketing, cost accounting, and production activities with their other team members using software tools from the Industrial Engineering computer laboratory. These tools included PowerPoint, Project, Excel, AutoCAD, Word, and various other programs to search for and create unique team artifacts, including the team logos and marketing materials. This report was presented at the awards ceremony.

Summary

The summer 2003 GEAR-UP Program activities at Texas A&M University-Commerce was possible with the assistance of three faculty members from TAMUC who volunteered to introduce area middle school students to the industrial engineering program and to engineering design principles as they exist in modern systems engineering programs. During the process of introducing students to the principles of engineering design and manufacturing tools and techniques, additional information was provided on project planning, cost accounting, marketing, test engineering, matrix management, and cross-functional team development skills. Students were actively involved in the process of creating functional paper airplanes that would perform well in their competitive arena. The results of the students' efforts were presented in a public forum where parents, teachers, and support staff gathered to recognize and congratulate the students on their achievements. The experience of Texas A&M University-Commerce faculty and staff during the summer 2003 GEAR-UP program was overwhelmingly positive and it is likely that future activities such as these will be created and administered in order to energize young students to consider careers in science and engineering. It is our belief that by capturing, focusing, and nurturing a student's interest in engineering during the middle school years (e.g. 7^{th}, 8^{th}, and 9^{th} grade levels), students will be more likely to feel confident in their own abilities through such exposure and positive experiences and in turn, favor engineering and science programs in the college years. The high percentage of female students who completed the GEAR-UP program is an encouraging sign that the long-held trend of relatively low female participation in science and engineering fields, may be reversed if we continue to expose students to the excitement and possibility of these challenging careers.

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Biography

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