Issues in Developing a High School Pre-engineering Program  

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Abstract - In an effort to increase awareness in science and engineering education in the northwest Florida region, the University of West Florida engineering department in conjunction with a local northwest Florida high school initiated a high school level pre-engineering program. Many issues were encountered in the first two years of the program. Primary issues in the deployment of the program included staffing, finance, enrollment, curriculum development, the development of instructional materials, and college credit award. Faculty level issues included the assimilation of university level faculty to the high school environment and the duality of faculty working between the university and high school systems. Student specific issues included student learning disabilities, English as a Second Language, and discipline in the classroom. Unique solutions were developed and applied to make the program a success. The following paper gives an overview of the program and solutions to some of the issues that were encountered. The goal is to present the approach taken in this particular program to give others who are developing similar programs insight into possible issues they may encounter.

Index Terms – Cooperative, Development, High School, Issues, Pre-engineering, University.

INTRODUCTION

In August 2003, the University of West Florida (UWF) and a local northwest Florida high school initiated a joint program that aims to teach high school students pre-engineering concepts and develop skills that will help them reach success in any university program. Many issues were encountered in the first two years of the program that required immediate solutions if the program was to continue. The first and most primary is that of gaining student interest and maintaining their motivation to pursue the program for four years. Other issues included staffing, finance, enrollment, curriculum development, the development of instructional materials, and college credit award. Faculty level issues included the assimilation of university level faculty to the high school environment and the duality of faculty working between the university and high school systems. Student specific issues included student learning disabilities, English as a second Language, and discipline in the classroom.

The first step to developing a framework was to examine the overall program for which these students would be entering. The type of program that was proposed and agreed upon is one that promotes critical thinking skills and high level reading comprehension through applications of math and science to real world problems in a structured four year pre-engineering program.

When developing any program, the goals of the program must be stated. The goals of this program are as follows:

- Increase and enhance awareness of the field of engineering among high school students.
- Develop problem solving skills and critical thinking skills in students.
- Increase hands on experience with real world problems.

Engineering, based in the Latin word Ingenium, means to be ingenious or creative. This places engineering in the realm of art because it uses math and science which are pure, to create solutions to real world problems [1]. These are often applications that if given to different people with the same set of skills, might have a different path of getting to the same place in the end. Thus, the nature of the solutions presented here. They are only one way that led to success. Success here is defined in the fact that current students are motivated to continue the program and meet the challenges set forth in the curriculum, and that new students want to join the program.

AN OVERVIEW OF THE PROGRAM

The purpose of this program is to create a seamless environment for students who think they might be interested in engineering, have the motivation and capability to enter the program in high school, and then after having participated in the program have the qualifications, skills, and motivation to enter a university engineering program and complete the program successfully. UWF hopes to channel some of these graduating students into its engineering programs.

The National Science Foundation (NSF) reports yearly statistics on the number of engineers enrolling in different types of programs throughout the United States [2]. The numbers are slowly dwindling. Something has to be done, or the United States faces what it faced in the 1950’s when the same thing occurred.

Historically about fifty percent of all qualified students who enter a four year university engineering program fall out of the program by the end of their second year. A research study was performed at Georgia Tech in collaboration...
between the Colleges of Physics, Psychology, and Education; in the study, discriminant analysis was utilized to isolate variables that would cause a qualified engineering student to drop out of the program. They were successful in isolating a variable, and developing an intervention to retain students. They found that they could pinpoint a specific class, Physics 3, in which they were losing their engineering students. These students were placed at risk because of a lack of mathematical concept which is used in a good part of the electromagnetic portion of that class. These students were failing out because of a curriculum that did not consider upstream downstream consequences of certain classes based in different departments. The researchers found that a certain class in Trigonometry was not structured to meet the needs of the curriculum. They remedied this by redesigning certain instructional blocks. They also developed a test to find students who were weak in this mathematical concept, and created a class to strengthen the students who were weak.

Many States have begun to assess students for similar reasons. The state of Florida, for example, uses the Florida Comprehensive Assessment Test (FCAT). In response to deficiencies found in student performance, Florida has implemented Immediate Intensive Intervention programs.

The goals of this pre-engineering program are based in the same principles: strengthen students through intervention before they arrive at the university level and retain them. The first year of this program began with UWF providing an instructor and Choctaw High School providing 33 students, and classroom and laboratory space. The program was designed to be a four year program. The courses include the following:

- **Freshman year:** Intro to Engineering is designed to introduce the students to engineering. The curriculum begins with a review of the different fields of engineering, and follows on throughout the year with lessons that last approximately three weeks each covering selected areas in depth.

- **Sophomore year:** Introduction to Electrical Circuits is designed to give the students the knowledge and skills required to work with basic electronic circuits. The students will spend the first part of the year in depth studying DC circuits and will have an introduction to applied robotics.

- **Junior year:** Engineering Computer Applications is designed to give the students programming skills and experience with engineering instrumentation. Java programming will be taught during the first semester with a slant toward engineering and engineering problems. The second half of the year will teach the students HTML, VRML, and metrology and instrumentation to include the application and interpretation of data collected from strain gauges, thermocouples, and accelerometers. The projects required during the second half of the year will be research oriented such as testing materials to destruct and collecting data from those tests.

- **Senior year:** Advanced Engineering Concepts & Senior Design is not unlike the senior design project that will be required of a college engineering student. The students will combine all of the skills from the three previous years to design, develop, and test an approved project in a team setting.

**INSTRUCTIONAL METHODS**

The following instructional methods have been developed for use in all levels of the program.

**I. Research**

Research sessions begin with the students performing research on a subject via the internet. The students are provided with a research packet that includes information that is both idealist and realist in nature. The Realist questions focus on the hard science behind any given engineering discipline. The idealist questions are Socratic in nature and push a student to perform deeper analysis of the data that they find to provide an answer that is their own. A fringe benefit of this research period is that it allows the students to strengthen their research skills under the supervision of a university faculty member.

**II. Lecture**

Upon completion of the research period which can be anywhere from a couple of days to a week, a lecture period begins. This lecture period is meant to clear up any questions and reinforce the concepts gained during the research period.

**III. Projects**

The final part of a lesson is a pragmatic approach in which the students are assigned a project that will require them to build something with their own hands. The purpose of these hands on projects is for students to learn by their mistakes. The students prepare proposals and the results of their projects in a team oriented environment. They are critiqued in a positive manner.

**IV. Critical Reading**

Students read books in this program that require them to think critically and analyze problems that others have encountered in both fiction such as in Dr. Isaac Asimov’s *I, Robot,* and

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**Figure 1**

**Students Tests Seawall Projects as Teams**
non-fiction such as in Dr. Henry Petroski’s *To Engineer is Human*. They are quizzed on this reading and required to give analytical answers to questions related to chapters in these books.

V. Problem Solving

Homework in this program is not the typical homework assigned in math and science where they take a page from the book and work problems. The type of homework here is meant to give them experience in looking at a variety of unrelated problems that require different thinking skills in each, and give several views from different directions. They are given problems on a weekly basis that require them to think outside of their experiences. Problems can range from: word, code, or math problems out of various brain teaser books; an essay arguing why robots should or should not be used in combat that is based on an article they are presented; code breaking complex codes using frequency analysis; or a problem in logic.

**ISSUES & SOLUTIONS**

I. Primary Issues

The primary issues involved staffing, finance, enrollment, curriculum development, the development of instructional material, and the award of college credit.

**Staffing**

The program was conceived during the summer of 2003 and initiated three months later in fall 2003. A regular university faculty member was assigned to teach two classes a day at the high school which was 60 miles away, in addition to his regular load at the university until a full time faculty member could be found for this position at the high school. A typical search for a candidate was carried out. Part of the agreement between the university and the high school was that the principal and an assistant principal would have the final say in who was hired to teach in their high school. They set up an interview process that would take place at the high school and the candidate not only sat through interviews with the hiring committee, but also had to present a pre-engineering lesson that he or she developed and present it to students. The principal and assistant principal observed the presentation and the students were required to rate the candidates as a homework assignment.

The initial search failed because the high school administration could not agree on a candidate who they thought would be able to adapt to the high school students as well as the high school environment. In the end the university professor who helped in initial curriculum development was selected to teach initial course offerings.

The administration’s policy complicated the search criteria. Past experience on their part taught them that this was crucial and they stuck by their position. In the mean time, this was affecting the university faculty member because he was in overload and no new candidate was in sight.

A second search was begun. The candidate chosen had industry experience, university as well as high school teaching experience, and experience as a flight instructor teaching young students to fly. This candidate had formal education in engineering, human factors, instructional technology, education, and instructional design and more important was interested in taking university classes to make up any deficiencies with respect to his areas of weakness. Administration was somewhat reluctant to hire this person however positive student input help settle the issue.

**Finance**

Budget is everything to an engineering program. It takes a considerable amount of money for startup programs for equipment, materials, and staff. Budget considerations should be considered over the first three years as different each year.

When the first discussions about this program took place, it was decided that costs would be a shared venture between the high school and the University of West Florida. In the first year of the program, the high school paid all costs. The university had no money the first year because none of this had been proposed in the budget of the university the previous year.

There was no capital equipment during the first year of the program. Grants were being pursued, but because the school is in a middle class to upper-middle class area, there were not enough free and reduced lunch students to qualify for grants with many of the major corporations that offer grants based on need. There are millions of dollars available for programs like this if the school has a high population of students with a low socio-economic status.

This left state vocational funds and high school money. During the second summer, a grant from the state was received. This grant was used to buy all needed equipment and consumables for two years.

Startup costs for the first year (2003-2004) of the program to include university overhead, faculty, books, capital equipment, and consumables was approximately $165,000. This was to teach 36 students. The second year (2004-2005) operating budget to include university overhead, faculty on an annual contract, and consumables was approximately $100,000 to teach 76 students. The projected budget will be approximately the same for the year (2005-2006) for an estimated 150 qualified students enrolled.

Once the numbers hit 150 students, state Full-Time Equivalent money (FTE) will begin to pay the majority of costs. In the state of Florida this is currently $3,800 for every six students enrolled in the program. Thus, 150 students equals about $95,000 in FTE. The university makes up the difference in cost as it considers this outreach to the community.

This solves the operating costs for years to come. However, one faculty member is too few, so grants from the National Science Foundation are being pursued to develop the program to the vision held by the school district, high school administration, the university administration, and the faculty.

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Enrollment

The selection process brings these students into the program with three things in common: One, they want to be there. Two, they have outstanding grades. Three, they have no major disciplinary problems. This is examined through transcripts and interviews.

The first year enrollment began very late. Since the program did not exist during the registration period of the previous year, students had to be contacted by phone for an interview to let them know that the program existed. Thirty-three were selected out of about fifty who were interviewed. Theses students had an average GPA of 4.0 coming into high school, meaning they were the cream of the crop. This set the stage for future selection because these students excelled in everything they did and even challenged the faculty. However, it was also determined that this would not be the final deciding factor in selection.

The first factor, desire to be there, is most important. If the student wants to be there, then they are motivated to learn and advance their knowledge and skills. Students also need to be made aware of what the classes are like and how grading is to be performed prior to enrollment. Many are timid because they see engineering as very complex and have very little knowledge of what is to come. Informing them of what to expect gives them a stronger self-efficacy and their motivation stays high. This is done during the interview process.

The second factor of grades is used to weed out the initial applicants who have extremely poor grades. This is done due to the fact that there are only so many slots available to the students. Some level of achievement and self regulation will also be required to be successful in the pre-engineering program, and grades are a good initial indicator of this factor. Most, if not all, students selected have had algebra by the beginning of ninth grade.

Each transcript is examined and if a student is found to have high grades in math, science, and technology, but poor grades in other areas, they are interviewed. If this candidate shows great interest and past aptitude for this program, they are informed that they will be accepted, but their grades must come up in all areas. Once they are in the program and understand why one needs to have good grades to get into engineering school, they tend to have a new motivation for performing in all areas.

The final selection factor is discipline. Applicants are screened for disciplinary problems. Any students with a record of class disruption no matter what their grades or desire to be in the program are rejected in the initial screening. So much material is covered, and so much time is spent in labs and projects, that it would be unfair to the rest of the students to allow disruption of class. There is no tolerance for poor discipline in the program.

Curriculum Development

The curriculum is based in the goals of the program. First, create an awareness of engineering. The program is linked to the Department of Electrical and Computer Engineering at UWF. However, the goal of the program is to create an overall awareness of engineering. Most of these students do not really know what an engineer does, much less what the difference is between a civil or mechanical engineer. This awareness is not only to teach them about the different types of engineering, but also how to become an engineer, where to go to school, how to get there, and even how to fund their education beyond high school.

The second part of the curriculum is to develop critical thinking skills in students. Some students have basic skills in this area coming into the program, but most do not. The curriculum goal is to plant seeds based in Idealist philosophy that will get the students thinking about the bases of thought and ideas. Other areas such as logic and ethics are also infused.

The time frame for curriculum development in the early stages of the program was short. The curriculum developed and the books selected were based on university texts. Many of these texts included mathematical concepts not yet encountered by the students. Some will see calculus in their senior year, but most will only get to pre-calculus. Also, many will not be introduced to physics or chemistry until their junior year, and even then they are not yet ready to completely make the connection and apply these concepts to engineering.

The question was posed, “Why not just teach them the math and science that they need?” The answer was that it would take so much time to do so, that it would defeat the purpose of the pre-engineering program. The math and science is to be taught by those departments. Therefore the curriculum was re-examined against the goals of the program. Again, the goal is not to make engineers out of the students, but to get them ready to pursue engineering. So, the texts were abandoned as primary instructional material and basic concepts were tailored to the level of the students’ current cognitive skills.

The material also needs to be within the domain of the instructor. The program requires the instructor to teach lessons over four years in Mechanical, Civil, Electrical, Ocean, Aerospace, Industrial, and Computer Engineering. Finding one faculty member who is versed in three of the above fields is possible, but all is tough. The answer of course would be to hire several faculty or draw from within the university, but selection and budget issues have already been discussed and definitely pose problems here.

The final part of the curriculum is to teach hands-on lessons using pragmatic methods of real world problem solving, team projects, etc. and existentialist methods of exploration, both guided and self autonomous. The goal of these hands on experiences is to enhance spatial ability which much of the literature suggests is important to success in chemistry, mathematics, and science which are the base tools of an engineer [4]. Much of engineering is taught in a 2D world out of a book or on a whiteboard. However, all of engineering is applied in a 3D world. Spatial ability is important because students need to be able to envision things that are often presented in 2D, in 3D in their minds. The idea is the more they gain hands on experience, the more patterns and concepts they will have of their environment, and the
more they will have to draw from when forming new concepts.

Development of Instructional Material

Since no books exist that cover all of the material needed at the proper level, material had to be developed. To do so, this required defining the instructional objectives set forth by the program, and then designing and developing material that met the criteria, and would make a connection with the students on their level. Thus formal lectures are used as well as hands-on experiments to reinforce the concepts gained. Students gravitate towards computers so online research and simulations are a great way to both deliver and reinforce materials. They also will spend a great deal of time learning to use new software.

II. Faculty Level Issues

The faculty level issues include the assimilation of university faculty to the high school environment, and then the duality of that faculty member existing between the university and the high school.

The first issue of assimilation simply means that any candidate must be informed of the following, and if hired professionally developed, and have university support while assimilating to the following:

- **Class Periods:** The high school class is 50 minutes per day. A lab only really has about thirty minutes between setup and takedown. The Classes are 5 days per week. Motivational issues due to attention would have to be addressed through instructional design and instructional methods [5].

- **Teenage Adolescent Behavior:** This is something that a college professor will have to get used to or they will not be able to teach in this environment. It may take several months to adjust when going from having taught young adults/adults to teaching teenagers. They do things for absolutely no reason at all. That has not changed and never will. They might glue a quarter, for example, to tables just to watch someone try to pick it up. They do not see this as vandalism, but merely a curiosity. A faculty member that deals with students with high IQs and the level of energy that these students have must be prepared to deal with these types of actions in a manner that is firm but positive.

- **Extraneous Activities:** Football games, pep-rallies, students leaving for fieldtrips, mock trials, FCAT, fire drills, school lock downs all detract from time in the classroom and you never know when one or the other will occur. Schedule flexibility is important. Teachers need to be able to keep blocks of instruction short. Because of disruptions, long sessions continued over a period of days can lead to disruption of the learning process and connectedness of material.

- **Emotional Issues:** Because these are adolescents, they have major things going on in their bodies and brains. The death of a student last year shut the whole learning process down for about a week and a half. It was bad! Anything can be a major issue to these students, and sooner or later something will interfere with their learning. A good teacher will recognize this in students and adapt the process to the needs of the students and school when the time comes.

- **School Rules:** The university faculty member in the high school is responsible for minors. Tardiness, absences, and breaking of rules have to be dealt with. Many university professors especially in engineering could care less if someone is there or not. Their attitude is that “If you don’t need to be and you can master the material by showing a grade performance, then good for you.” If you can’t then they could care less if you drop or fail out. This cannot be the attitude in the high school. If a kid is not in your classroom, then they could be out getting hurt or killed. It is often easy to see some of them as adults because they are on the verge of adulthood. Some are even 18, however, the faculty member must be made aware as to why and how to be responsible for these kids while they are supposed to be in their class.

- **Faculty Development:** Due to accreditation requirements, the faculty member teaching this program must hold a Master’s in Engineering or an Engineering related discipline with an undergraduate degree in engineering. This means that this faculty member is most likely not an educator by instruction, but by imitation. They must be trained in instructional design and they...
have to be professionally developed to the point where they understand the pedagogical grounding of the curriculum and instruction of the program.

- **Space**: Lots of space is needed. Works in progress often cannot be moved. There needs to be lots of space in which things can get messy. Engineering is functional and also needs functional spaces in which to work on and develop projects. This space also needs to be secure because much of the equipment is expensive and sometimes fragile.

- **Technology**: Lots of computers for online research, computer simulations, and distance learning capabilities should be available.

- **Instructional Designers**: If an instructional designer is brought in, that designer needs to be familiar with the fact that engineers quite often speak a different language. The concept the engineer is talking about might not be the concept the designer is getting. Communication between the two and clarity of concept is of the utmost importance.

**Duality**

The faculty member who is hired must exist and interact with two organizations similar in the fact that they educate, but dissimilar in nearly all other aspects. The high school methods and policies regarding budget expenditures, material purchases, disciplinary actions, etc., must be learned by the faculty member. Some things are bought through the university and some things are bought through the high school. High school budgets are very specific as to how funds can be spent. Improper use of those funds can ultimately lead to disciplinary action against the high school administration.

Lack of support from within the high school or the university by fellow faculty members can be detrimental to the program. This means that faculty members must attend social functions and faculty meetings at both institutions which can become very time consuming.

**III. Student Issues**

There are students with excellent grades who have learning disabilities or are have English as a second language (ESOL) classification. These students sometimes have to work harder and still test poorly, but can give evidence of their learning. This is an interesting area that warrants research, because in the end, these students already have skills that make them an asset to any organization and good engineers in industry because they have great coping skills and have already mastered self-regulated learning and compensation. High schools deal with this problem rather well by developing personal plans for the students to help both teachers and students deal with their disability. The problem is that with the current status quo of the realist/behaviorist approach to discipline.

The instructional methods for this program have been developed so that all students get an equal chance to perform in the areas that they are good at in the beginning. As they develop skills throughout the program, they are pushed further and further until all the students are on even ground. This is done by using a number of different instructional methods. Grades in this program are a result of hard work and demonstration of what is learned and applied, not test taking abilities.

Poor behavior is one thing that is not accepted in the program. Talking and moving around the classroom is part of the social experience of this class. A history of rudeness, disrespect, violence, skipping class, or lack of following directions on the part of the student is not tolerated in the pre-engineering program and these students are quickly removed. Thus, the realist/behaviorist approach to discipline.

**CONCLUSION**

The program presented here is just one approach to introducing students to engineering and preparing them for engineering education at the university level. The solutions are unique to this program and to the high school and school district in which it is taught. However, many of the issues are not. Those involved in this program have learned that careful consideration of program goals and a curriculum that aligns with those goals; faculty selection and preparation; and solid, level specific instructional materials and proper delivery of those materials are the first step in the right direction.

**REFERENCES**


