An Integrated Freshman Curriculum

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Abstract - This paper describes a four course sequence that is being taught during the first two years of the engineering curriculum to simulate the concepts of vertical integration. The sequence is implemented within existing curricula and is designed to provide an alternative procedure for vertical integration of material that works within current frameworks, to increase student retention between the first and second year of engineering curriculum, to enhance the educational experience of engineering students through the integration of mathematics, physics, chemistry, and engineering science, to produce engineering students that are creative, critical thinkers and mature independent learners, and that are aware of the engineering role in society as a whole. The four course sequence will be presented and discussed and preliminary results for the first year of implementation will be presented.

Introduction

The first two years of any engineering curricula are key to whether a student stays in engineering and to whether he develops many of the desired attributes of a good engineer. Since these first two years are critical, much attention has been given to them and engineering education in general over the past decade. This is seen in NSF funding and from ASEE's *National Action Agenda for Engineering Education*.

From the attention devoted to this problem it appears that a feasible direction to follow is the concept of "vertical integration" where natural science, mathematics, and engineering science all come together through the use of meaningful applications and developments. The ideas behind this are good and there appears to be many benefits to this holistic concept. It should be noted that this concept is not new and is actually being implemented at the elementary school level in many places across the country and is one of the standards put forth by the National Council of Teachers of Mathematics. Likewise, several universities are in the process of implementing integrated curricula. This is time consuming and quite costly. The program at Rose-Hulman Institute is an excellent example.

The problem, however, is that not all schools can afford to implement an "integrated" curriculum due to such things as limited resources, budget constraints, and politics, to name a few. Curricula has tremendous inertia and is resistant to all but small or superfluous changes, especially in the political arena. Likewise, if one is able to implement curricula changes then one needs to also consider what can or should be done for while implementing the changes during the transition period, which can be a time-consuming, tedious process. The question then becomes "Is there a financially feasible way in which a school can simulate vertical integration and obtain it's benefits while in the process of changing curricula or fighting political battles for change, without having to change curricula entirely?" It is the purpose of this research to determine if it is possible to simulate vertical integration of curriculum.

Goals and Specific Objectives

The goals of this project are virtually the same as those outlined by the Undergraduate Curriculum Development program [12] and ASEE's *National Action Agenda for Engineering Education* [1]. Those goals can be stated as follows:

Goals: Developing a curriculum through which each engineering student develops

1) *Analytic Ability*: the ability to think critically,
2) *Integrative Ability*: the ability to recognize the engineering process as an integration of analysis and synthesis with regard to societal need,
3) *Contextual Understanding*: to appreciate how engineering fits into and influences the social, economic, industrial, and international environment in which it is practiced,
4) The ability to create and implement systems, products, and methodology,
5) The ability to be an effective, independent learner.

The specific objectives that will support the realization of these goals are

Objectives:

1) Design a concurrent curriculum to simulate vertical integration for first and second year students.

2) Design each course in the curriculum so as to meet the needs (social and academic) of first and second year students.
3) Design each course to be as "instructor- bias" free as possible. That is, each course will stand on its designed approach and content not on who is teaching it.
4) Each course will utilize real world "living" case studies.
5) Each course will utilize designed software to allow students as much interaction and "hands-on" experience as possible.
6) Each course should employ a discovery oriented learning environment.
7) Each course will promote intellectual growth.
8) Each course will have integrated components of writing, decision-making, communication and historical and societal perspectives.
9) Each course will complement the core curriculum offered at that time.
10) Concerns of under represented populations must be taken into account.

Project Description

This project will be accomplished through the use of a four course sequence spanning the first two years (4 semesters). One course will be offered each semester and will be designed, with input from physics, mathematics, and chemistry, to correlate with the standard core curriculum of that semester. The particular class will integrate the concepts being taught that semester into the ongoing class projects and will reinforce the concepts through applications, hands-on experience and multi-media computer aided projects. In addition, the first course of the sequence will be designed to also try and help the student during the transition into college academics. Each of the four courses is described in more detail below.

Semester 1 - Core Curriculum: Calculus I - 5 hours, Introduction to Programming - 3 hours, Engineering Graphics - 3 hours, Concurrent Course 1 - 1 hour, Humanities Elective - 3 hours

Concurrent Course 1: Introduce the student to the use of the computer as a learning tool and as an analytic tool. Help the student see the uses of and understand the fundamentals of analytic geometry, derivatives, integration and engineering graphics.

Sample Objectives and Assignments

1) Introduce the student to and teach the student how to use computer tools to help aid the learning process. Such tools would be word processing, spreadsheets, windows, MATHEMATICA, MATLAB, computer aided geometry, MATHCAD, etc. Note also that the Calculus sequence is already taught using MATHEMATICA.
2) Introduce the student to a real world engineering problem through the use of a case study and to the engineering process through a historical review of the case.
3) Provide the student with a historical framework and context for how and why calculus was derived and for the variety of applications it has. Do the same for Programming and Graphics.
4) Provide peer support for the student through periodic "communication" sessions in which students participate in an open ended discussion with the professor about classes, applicability, usefulness, anything of their choice. Also help the students to develop peer study groups for cooperative learning.
5) Establish the multimedia learning center as a support center for the students' learning needs.
6) Establish and require the use of a logbook to track the work the student is doing, the concepts that are being learned, and to help teach time management and decision making procedures. These logbooks will be carried throughout the four course sequence and will be graded and use for evaluation of the courses.
7) For the given case study have the student write a paper and present results related to some aspect of the problem that can be addressed by concepts that are currently being learned. Leave the problem open ended so that the students may possibly create their own procedures for the problem. Require however, the use of computer tools in the analysis and at least two possible solutions to the problem.
8) Have periodic "brainstorming" sessions related to the case study or some other known engineering problem, i.e. "Why does the tower of Pisa lean and how could it be corrected?, "How can satellites be used to keep track of infantry men?", "How does a T.V. really work and how could it be improved?" and so on.

Semester 2 - Core Curriculum: Calculus II - 5 hours, University Physics I - 5 hours, General Chemistry - 3 hours, Concurrent Course 2 - 1 hour, Humanities elective - 2 hours

Concurrent Course 2 - Helps the student start to understand the relationship between calculus, physics, chemistry and engineering and how they are integrated together to solve or model a problem. Continues to stress the use of the computer as a tool of investigation to help in the learning process. Helps establish the fundamentals of calculus, chemistry, and physics.

Sample Objectives and Assignments

1) Continue the use of the computer as an investigative tool. Give assignments based on the available software that highlight how calculus and physics are interwoven. Use graphics software as much as possible and link current concepts with those learned in the previous semester.
2) Continue analysis of the case study with the new concepts as they are learned. Use the case study as an obvious application area for each technique or procedure learned in the previous semester. Likewise, identify and use concepts from physics, chemistry, and calculus in the analysis of the case study.
3) Assign and discuss as a group a project that involves the use of all three core courses. Have example projects on the multimedia system for student viewing. Have projects that fail as well as succeed.
4) Investigate and study the life of Newton. Use this as an opportunity to show that originally mathematics, physics and engineering were all considered together and that they generated each other. Discuss the engineering problems of Newton's day and how they lead to many of his discoveries in math and physics. Newton and Da Vinci are classic examples of how math, science, and engineering are truly integrated.
5) Continue development of peer support and study groups.
6) Supplement the calculus, chemistry, and physics courses with many examples that clearly integrate the courses. Do this through class discussions and assignments within the multimedia learning center.
7) For each student select a current technology that is visibly understandable. Have the student write and present a report discussing as many applications of calculus, physics, and chemistry as possible within that technology and its production.
8) Have the students maintain their logbooks and to start including self assessment in the log and questions the students cannot answer or find the answer to.

Semester 3 - Core Curriculum: Calculus III - 3 hours, University Physics II - 5 hours, Statics - 3 hours, General Chemistry - 3 hours, Concurrent Course 3 - 1 hour

Concurrent Course 3 - Helps the student see and understand the relationship between calculus and physics and the application of physics in engineering. Helps the student see and understand how mathematics is essential to solving physics problems and how physics is essential in solving many engineering problems. Continues to stress the use of the computer as an investigative tool, the use of previous concepts with current ones, and management and decision making skills.

Sample Objectives and Assignments

1) Continue the use of the computer as an investigative tool and introduce its uses as an analytic tool to help in the design of procedures.
2) Use designed software to have students do assignments that integrate calculus, physics, and statics. A primary example would be the use of vectors and the testing of forces on different designs using computer graphics.
3) Have students do assignments related to actual applications that involve the use of what they have previously learned as well as what they are currently learning. For example, one can have the students design an adjustable basketball goal and test the design integrating what they have learned the past two semesters.
4) Have students review the past two semester reports on their case study. Have them update and re-analyze the case study based on the new information they have obtained.
5) Use physics and appropriate examples, such as electro-mechanical analogs, to introduce the students to the engineering concepts they will be studying in the their coming curriculum. Also introduce the student to the concept of optimization as an area of application that integrates calculus, linear algebra, physics and engineering in general.
6) Do a study on how math and physics were used to build pyramids and castles. Contrast the different styles and analyze the procedures. What techniques are still used today and how would the student do it differently using the tools available at that time? What was the relationship of math, physics, and engineering at that time?

7) Based on the case study, assign a project that will be due at the end of the following semester. This project should be open-ended and require the use of the material they have learned. The project should also require alternate solutions and be something that can be compared to what is actually done at the company. The desire is to have the students' designs and problem solving techniques evolve over the 2 semesters. Have students do 1 page progress memos as a way to track the process and to keep them involved. Have students work in groups.
8) Have the student maintain the logbook and add to the log a requirement for 2 observations a week of where what they have learned is being used in the real world around them.

Semester 4 - Core Curriculum: Differential Equations - 3 hours, Introduction to Modern Physics - 3 hours, Dynamics - 3 hours, Circuits - 3 hours, Concurrent Course 4 - 1 hour, Humanities Elective - 3 hours

Concurrent Course 4 - Helps the student integrate all past concepts with current concepts and see their use in the application to current material and beyond. Helps student use these concepts to start modeling engineering problems and proposing solution techniques. Helps student combine past and current concepts along with computer techniques and software to suggest solutions to real world problems.

Sample Objectives and Assignments

1) Give 3 different assignments that require the analysis of a process and a product. Each one should require the use of concepts they are currently learning and concepts they have learned.

2) Use the multimedia center for assignments and tutorials that show the uses of and need for calculus and physics in each of the engineering sciences.
3) The students should be able to model simple engineering problems mathematically and have a feel for the complexity of actual problems.
4) Have students write a paper discussing the interrelationships of each of the engineering sciences with each other and the mathematics and physics they have learned. Have the student identify one current technology that uses all of the concepts they have learned in some form.
5) Have bi-weekly discussion sessions related to the projects dealing with the case study. Emphasize application of what they have learned, time management, decision making, resource constraints, and management constraints. Discuss tradeoffs between optimal solutions and "good" solutions. Make these open ended, learning experiences.
6) Have students do assignments in the multimedia lab that are open ended and help the student discover concepts and facts that they will be learning in their classes.
7) Have students maintain their logbooks and add thoughts associated with the frustrations and highlights encountered in their projects.
8) Have students present final reports on their projects with a summary of all the concepts they have learned that were used to solve the problem. Make sure students have alternate solutions, comparative analysis, and suggestions for future improvements.
9) Have the students write a paper based on their logs describing what they have learned, what they think they will do with it, and what they see their role and engineering's role being in society today and in the future.

The supposition behind each of these courses is that the assignments and projects are designed to be self paced and to facilitate learning through discovery and experimentation.

These courses have been offered in the College of Engineering in lieu of one 3 hour technical elective. Each one hour concurrent course though, will be viewed as a lab class and will actually constitute a minimum of 2 hours per week of contact time.

For this initial study 20 incoming freshmen will be chosen at the beginning of each academic year for the concurrent courses. These students will be used as the test bed to determine the effectiveness of this project. The students will be chosen from a cross section of the incoming freshman to obtain as random and nonhomogeneous a group as possible. However, the population will be chosen so that demographic makeup is equivalent to the general student population with 50% women and 30% minority students. The students will be allowed to decide not to participate if they choose. The desire is to obtain a student population that would reflect the overall student body and not bias the results of the experiment. It is assumed, since different students have different learning styles, that by randomly selecting students, some will perform well and some will not. The question though is what is the level of learning compared to the traditional student body? That is, it is believed that through the concurrent courses it will be able to be shown that those students who perform poorly in the concurrent course sequence will still have learned more and developed life long skills that those students performing poorly in the traditional sequence will not.

Initial Results

The first year of this program has been completed. One must realize though that no actual conclusions can be drawn from the initial data. This is because the sample size is too small and the population may be biased. Even though students were chosen randomly, they were not forced to participate in the course. Only those students who said they would be willing to stay in the program for two years were placed in the course. It may be that only better or more interested and self motivated students would choose to do this. We do not know for sure, therefore the results should be viewed as anecdotal for now.

The students that completed the first year had significantly higher GPAs than the general engineering student body and the retention rate of these students was higher than for the general engineering student body. This would possibly indicate that the course is doing what it was intended to do. However, the question remains as to whether the better qualitative results are do to the integrated material or to just having the students feel apart of engineering and the study groups and peer structure they were able to develop.

Log books and surveys taken indicate that all the students viewed the courses as their favorites. They truly enjoyed the hands-on activities and felt as if they were actually doing and being engineers. The plant trips were also very well received. The major complaint of the course was that there was not enough time to do the activities and that they wanted to spend more in class time working on projects. Another complaint was they did not feel that the multimedia software they were required to use enhanced their learning or understanding. This and other software is being re-evaluated.

Overall, it appears that the course is having a positive impact. The exact reasons for the impact can not be isolated at the moment, but in a sense it does not matter as long as the students are remaining in engineering and feel their engineering curriculum is being strengthened.

Acknowledgments

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References

[1] *A National Action Agenda for Engineering Education*, report of the Task Force on a National Action Agenda for Engineering Education (Edward E. David, Chairman), ASEE, Washington, D.C., 1987.

[12]E. Ernst, "Revitalizing Undergraduate Programs: Curriculum Development," *Engineering Education*, Vol. 79, No. 1, January 1989, 20-24.